State of California
Natural Resources Agency
Department of Fish and Wildlife

REPORT TO THE FISH AND GAME COMMISSION

FIVE-YEAR STATUS REVIEW OF RIPARIAN BRUSH RABBIT (*Sylvilagus bachmani riparius*)

February 21, 2020

Riparian Brush Rabbit, Lee Eastman/USFWS

Charlton H. Bonham, Director
Department of Fish and Wildlife

TABLE OF CONTENTS

I. EXECUTIVE SUMMARY

The riparian brush rabbit (*Sylvilagus bachmani riparius*) is currently listed as endangered in California. Pursuant to Fish and Game Code § 2077, subdivision (a), the California Department of Fish and Wildlife (Department) has prepared this Five-Year Status Review to evaluate whether conditions that led to the original listing of riparian brush rabbit are still present. This review is based on the best scientific information currently available to the Department regarding each of the components listed under § 2072.3 of the Fish and Game Code, and section 670.1, subdivisions (d) and (i)(1)(A), of Title 14 of the California Code of Regulations. In addition, this document contains a review of the identification of habitat that may be essential to the continued existence of the species, and the Department's recommendations for management activities and other recommendations for recovery of the species (Fish & G. Code, § 2077, subd. (a)).

After reviewing the best available scientific information, the Department determined the following:

The riparian brush rabbit (*Sylvilagus bachmani riparius*), a subspecies of brush rabbit (*S. bachmani*), was listed as endangered under the California Endangered Species Act in 1994 and listed as endangered under the federal Endangered Species Act in 2000. Riparian brush rabbits are relatively small, brownish, and lack the conspicuous white tail of similar cottontail rabbits. Riparian brush rabbits live in dense riparian (streamside/riverside) vegetation in the San Joaquin Valley and Delta and forage on herbaceous vegetation including grasses, sedges, clover, forbs, shoots, and leaves. They seldom venture more than a few meters from brushy cover and occupy small home ranges (<2 ha [<5 ac.]). They breed seasonally, have low reproduction rates relative to other rabbit species, and most individuals do not live longer than one year in the wild. Predation is the cause of most mortality under normal conditions and they are preyed upon by a wide variety of native and non-native predators. Riparian brush rabbits compete with desert cottontails (*Sylvilagus audubonii*) in much of their range and are subject to a wide variety of potentially deadly diseases.

Little is known about the historical distribution of riparian brush rabbits, although they likely occupied most of the riparian habitat along San Joaquin Valley rivers and streams. Today they are limited to areas of the southern San Joaquin River Delta, remnant and restored riparian zones along the lower San Joaquin River north of the Tuolumne River, and riparian forests of the lower Stanislaus River. The subspecies population has fluctuated widely in recent times due to severe population crashes during periodic flood events, and the actual population size is unknown. An ambitious habitat restoration and repatriation effort in the early 2000s has resulted in a significant increase in occupancy within the historical range and increase in the population.

The major threats to the persistence of riparian brush rabbits include the dramatic historic and ongoing loss of San Joaquin Valley riparian habitat; fragmentation of remaining habitat patches which limits the ability of rabbits to disperse and exchange genetic material; catastrophic periodic flood events coupled with the limited availability of high elevation habitat for rabbits to

retreat to during floods; habitat loss and mortality from wildfires; predation from native and non-native predators; environmental and genetic threats inherent to small, isolated populations; climate impacts; and rodenticide exposure.

Recent management efforts have substantially expanded the occupied area within the historical range and improved the viability of southern riparian brush rabbit populations. From 2002 -2013, an intensive captive propagation and translocation effort resulted in the release of 1,496 riparian brush rabbits onto the San Joaquin River National Wildlife Refuge (Refuge). During the same period, the Refuge was dramatically expanding in size and restoring vast areas of farmland to riparian brush rabbit habitat. Despite these important recovery actions, most of the extant riparian brush rabbit populations remain threatened by catastrophic flood events. Future management of the riparian brush rabbit must address the range-wide risk of flooding by securing flood-safe riparian habitat adjacent to existing local populations. Other future management needs include the development of a riparian brush rabbit recovery plan, basic biological research on the diet and ecology of the subspecies, and the development of efficient monitoring techniques.

The Department recommends no change to the riparian brush rabbit's endangered status.

II. INTRODUCTION

A. Five-Year Status Review

This Five-Year Status Review addresses the riparian brush rabbit (*Sylvilagus bachmani riparius*) (Orr 1935), which is designated as an endangered species under the California Endangered Species Act (CESA) (Fish and G. Code § 2050 et seq.; Cal. Code Regs. tit. 14 § 670.5, subd. (a)(6)(A)). Upon a specific appropriation of funds by the Legislature, the California Department of Fish and Wildlife (Department) shall, or if other funding is available, in the absence of a specific appropriation, may, review species listed as endangered or threatened under CESA every five years to determine if the conditions that led to the original listing are still present (Fish and G. Code § 2077, subd. (a)). The riparian brush rabbit is also listed as endangered under the federal Endangered Species Act. Pursuant to Fish and Game Code § 2077, subdivision (b), the United States Department of the Interior, U.S. Fish and Wildlife Service (USFWS) was contacted in an effort to coordinate this status review with their five-year review process. The USFWS is currently preparing a Species Status Assessment which will be used as part of a federal five-year status review in the near future (Stephanie Prevost pers. comm. 6/13/2019).

Using the best scientific information available to the Department, this Five-Year Status Review includes information on the following components pursuant to § 2072.3 and § 2077(a) of the Fish and Game Code and § 670.1(d) of Title 14 of the California Code of Regulations: species' population trend(s), range, distribution (including a detailed distribution map), abundance, life history, factors affecting the species' ability to survive and reproduce, the degree and immediacy of threats, the impact of existing management efforts, the availability and sources of information, identified habitat essential for the continued existence of the species, and the

Department's recommendations for future management activities and other recovery measures to conserve, protect, and enhance the species.

B. Listing and Status Review History

Riparian brush rabbits were listed as endangered under CESA in 1994. At the time of the initial listing the main identified threats to the species included: extensive loss of historically occupied habitat to agricultural development; small population sizes threatened by floods, fires, and other environmental events; deleterious genetic trends associated with small populations; and competition with desert cottontails (*S. audubonii*). The Department has not previously conducted a 5-year Review of this subspecies.

A 1998 federal Recovery Plan for the Upland Species of the San Joaquin Valley discussed the riparian brush rabbit. However, the subspecies was not listed under the federal Endangered Species Act at that time and therefore, while the plan included directed actions to improve riparian brush rabbit populations, recovery criteria were not included (USFWS 1998). On February 23, 2000 the subspecies was listed as endangered under the federal Endangered Species Act of 1973 (16 U.S.C. § 1531 et seq.).

This Five-Year Status Review was prepared by Daniel Applebee in the Department's Wildlife Branch Nongame Program with input from Jennifer Rippert (Bay Delta Region), Henry Lomeli (North Central Region), Reagan O'Leary (Central Region), Stephanie Prevost (USFWS Sacramento Field Office), and mapping support from Kristi Cripe (Wildlife Branch).

III. BIOLOGY

A. Taxonomic and Physical Description

i. Physical Description

Riparian brush rabbits are small, brownish, cottontail-like rabbits with white bellies, relatively short ears, and small inconspicuous tails. Adults are about 300-375 mm (11.8-14.8 in.) long. The hind legs are short and hind feet are slender and not covered with long or dense hair. The pelage (fur) is pale gray on the sides, darker on the back. The ears lack dark areas at the tips which are typical of the more ubiquitous desert cottontail (also known as Audubon's cottontail), (Orr 1935, 1940; Ingles 1965; Chapman 1974). The riparian brush rabbit can be distinguished from other subspecies by its relatively pale color, gray sides, and darker back (Orr 1935), its restricted range and habitat requirements, and skull characteristics (Orr 1935, 1940).

The similar desert cottontail occurs within the range of the riparian brush rabbit and can be found inhabiting the same patches of riparian habitat. Desert cottontails are found in a wider variety of habitat types, are slightly larger, have larger eyes and ears, are more yellowish in coloration, and have dark-tipped ears and a very conspicuous tail (Ingles 1965).

ii. Taxonomy

The riparian brush rabbit is recognized as a distinct subspecies of the brush rabbit. There are 13 recognized subspecies of brush rabbit, eight of which occur in California (Hall 1981). Brush rabbits are found along the Pacific Coast of North America from the Columbia River to the tip of Baja California and from the western slope of the Cascade-Sierra Nevada Range west to the Pacific Ocean (Orr 1935, 1940; Chapman 1974; Hall 1981). Orr (1935) described the riparian brush rabbit with the type locality designated as the west side of the San Joaquin River, two miles northeast of Vernalis, Stanislaus County, California.

B. Life History and Ecology

The information below is largely reproduced from the Department's 1993 Status Review (CDFG 1993) which summarized what is known about riparian brush rabbits from technical information provided in Orr (1935, 1940), Chapman (1974), Chapman et al. (1982), Williams (1986, 1988, 1993), Williams and Basey (1986) and Basey (1990). Where new information is presented it is referenced.

i. Food Habits and Foraging Behavior

Riparian brush rabbits forage on a wide variety of herbaceous vegetation, including grasses, sedges, clover, forbs, shoots, and leaves. The vegetation is generally clipped off using the teeth while the animal moves slowly along the ground. Occasionally, an animal will rise up on its hind legs to reach a slightly elevated item, but edible items are not manipulated by the forepaws. Vegetation is eaten in available areas within or very close to brushy cover, usually along trails, fire breaks, or at the edge of brushy areas. They seldom venture more than several meters from brushy cover, and do not forage in large open areas. Foraging activity occurs during the early morning and early evening hours. Basey (1990) observed brush rabbits feeding on a variety of vegetation including wild rose (*Rosa* spp.*),* blackberry (*Rubus* spp.*)*, blue elderberry (*Sambucus nigra* ssp. *caerulea*), California wild grape (*Vitis californica*), dried oak leaves (*Quercus* spp.), and grasses, including bermudagrass (*Cynodon* spp.). Grasses appeared to be the most important food source when available, followed by the growing tips of wild rose and blackberry shoots. Brush rabbits are known to practice coprophagy (re-ingestion of feces), presumably to extract additional nutrition from incompletely digested food (Chapman and Litvaitis 2003).

ii. Home Range and Population Densities

Home ranges of male and female riparian brush rabbits become larger during the breeding season (Kelt et al. 2014). At Caswell Memorial State Park (hereafter referred to as "Caswell Park"), Basey (1990) found the mean male home range (0.096 ha [0.24 ac.]) to be larger than the mean female home range (0.02 ha [0.06 ac.]). Male home ranges overlapped several female home ranges, but the activity centers of female home ranges did not overlap. Densities ranged from 2-14 rabbits per ha, (2.47 ac.), depending on habitat quality.

Hamilton's (2010) study of translocated riparian brush rabbits on the San Joaquin River National Wildlife Refuge (hereafter referred to as the "Refuge") documented considerably larger home

ranges, averaging 1.79 ha (4.4 ac.), with male home ranges only slightly larger than female home ranges. Riparian brush rabbit home ranges were slightly larger during the breeding season than in the non-breeding season - 1.97 ha (4.87 ac.) versus 1.60 ha (3.95 ac.). Hamilton (2010) observed a reduction in average home range sizes over the three year course of her study and postulated that rabbits may have spent the first season following translocation in search of suitable habitat or potential mates; but as the local population on the Refuge increased through additional releases and local births, suitable habitat might have become limited, resulting in smaller home ranges.

iii. Reproduction and Survival

Riparian brush rabbits breed seasonally, unlike the desert cottontail which can breed all year (Mossman 1955; USFWS 2000). Williams (1988) and Basey (1990) found that wild riparian brush rabbits breed from February to May or June. In breeding enclosures, riparian brush rabbits were polygynous, with one male dominating the mating of most females, but not to the exclusion of all other males. In captivity, female promiscuity was observed, with some litters fathered by more than one male (Williams et al. 2005; Williams et al. 2008).

Hamilton (2010) estimated the proportion of breeding females in the wild local population on the San Joaquin National Wildlife Refuge was approximately 46%. Williams et al. (2008) found some females in captive propagation facilities produced up to four litters per season; however, most females had only one or two litters. Breeding females produced an average of 5.3 young each season, while only 2.8-2.9 young per pregnancy survived more than a few weeks after birth (Williams et al. 2005; Williams et al. 2008).

Shallow ground nests are typically located under large clumps of dense blackberry vines. Constructed and found burrows may be also be used (Orr 1940; Williams et al. 2008). The gestation period is 27-30 days. Young open their eyes ten days after birth and leave the nest at about two weeks, although the female may continue to suckle her young two to three weeks after their birth (Orr 1940, 1942). Young riparian brush rabbits reach adult size in approximately four to five months and in captivity reach sexual maturity at approximately four months (USFWS 2000; Wittmer et al. 2016). Kelly and Holt (2011) monitored one captive-bred translocated riparian brush rabbit on the Refuge for over three years, but most reproductive rabbits do not survive to the next breeding season due to predation, disease, and other causes (Williams et al. 2008).

iv. Activity Patterns and Dispersal

Riparian brush rabbits are crepuscular, typically active in the evening between sunset and 0200 hrs., and in the morning from 0600-1030 hrs. Between active periods, they groom and rest in small depressions or elevated on downed logs and may sun themselves during sunny afternoons. These resting locations are connected by a maze of well-used runways. When being chased, riparian brush rabbits are difficult to flush into the open and instead stick to dense cover or climb up into vegetation. They will also climb into small trees or snags when necessary to escape flooding.

Dispersal patterns are generally unknown. It is assumed that animals may travel a very short distance when necessary to find a suitable unoccupied home range within riparian habitat during the breeding season. They are closely restricted to dense brushy cover and are probably unable or unwilling to disperse through large open areas. Studies of the closely related subspecies, *S. bachmani ubericolor* found rabbits that were displaced > 350 m (1,148 ft.) from their home range had difficulty returning to their original territory. Due to this rather short homing ability, animals displaced by floods may not be able to return to their original location.

v. Predators, Competitors, and Disease

Riparian brush rabbits are preyed upon by various native raptorial and carnivorous species that normally occur within riparian habitat, such as hawks, owls, coyotes (*Canis latrans*), foxes, long-tailed weasels (*Mustela frenata*), and snakes. They are also susceptible to predation by feral dogs (*Canis familiaris*) and cats (*Felis catus*) (Williams 1988). Predation was the greatest cause of deaths in translocated rabbits on the Refuge (Williams et al. 2008).

The riparian brush rabbit's main competitor for food resources is the desert cottontail. Riparian brush rabbits are subject to diseases and parasites that typically affect North American rabbit species, many of which are contagious and fatal. Amongst captive and translocated rabbits, when disease was determined to be the likely cause of death, *Baylisascaris* spp. (a parasitic roundworm) was most often implicated. Other diseases implicated in deaths were necrotizing typhlitis, and intestinal lymphoma (Williams et al. 2008).

C. Habitat Necessary for Species Survival

Riparian brush rabbits are restricted to the native San Joaquin Valley riparian habitat originally found on the valley floor in the floodplain of the San Joaquin River and tributaries. Historically, periodic flooding occurred during natural variations in precipitation and snowmelt (Das 2013). These floodplain areas were uneven, with enough topography that upland areas with appropriate vegetative cover were available for retreat during flooding (Katibah 1984). Riparian brush rabbits are strictly confined to patches of habitat with dense brushy and herbaceous groundcover totaling ≥ 460 m^2 (5,000 ft^2). They seldom venture > 1-2 m (3.3-6.6 ft.) from brushy cover. Open areas and areas where willows predominate but ground cover and litter are regularly removed by scouring flood flows and prolonged inundation, are not typically used by riparian brush rabbits.

Riparian brush rabbits inhabit two types of riparian vegetative communities; old-growth riparian forest (primarily dominated by valley oak, *Quercus lobata*) with dense shrub and vine understories, and riparian communities dominated by thickets of willows (*Salix* spp.), wild roses, blackberries, California grape, and other successional trees and woody plants (Kelly et al. 2011). Kelt et al. (2014) found a disproportionate preferential use of the latter type. Herbaceous forbs at the edge of shrub cover appear to be an important habitat feature, providing both cover and forage. Important forb species include mugwort (*Artemisia douglasiana*), stinging nettle (*Urtica dioica*), and gumplant (*Grindelia camporum*). While riparian brush rabbits do not venture far from dense cover to forage, open fields in close proximity to cover are used (Kelly et al. 2011). Vegetative structure is also important; the presence of trees

and shrubs that grow to heights above periodic floods is critical during temporary high-water conditions. Tall trees and shrubs are also important, providing structural scaffolding for blackberry and rose to climb (Kelly et al. 2011).

IV. DISTRIBUTION AND ABUNDANCE

A. Range and Distribution

i. Historic Range and Distribution

The historical distribution of riparian brush rabbits is largely unknown. Orr (1940), based on only five records, believed riparian brush rabbits occupied the native riparian forests within the natural floodplain along the northern portion of the San Joaquin River and its tributaries from Stanislaus County to the Delta. Williams and Basey (1986) speculated that riparian brush rabbits were historically distributed within riparian forests where there was likely ample brushy understory and suitable upland areas for cover and retreat from annual floods within the San Joaquin Valley floor. In the mid-1980's the area of potentially occupied riparian habitat along the San Joaquin River and its tributaries north of the confluence of the San Joaquin and Merced Rivers was estimated to have totaled approximately 39,800 ha (98,300 ac.) (Katibah 1984).

At the time the riparian brush rabbit was listed by the State of California, Caswell Memorial State Park contained the only known population of the subspecies. Caswell Park is located on the northern bank of the Stanislaus River in southern San Joaquin County and contains one of the largest remaining fragments of mature riparian forest habitat within the San Joaquin Valley, totaling 104 ha (258 ac.). In 1998, a few riparian brush rabbits were discovered persisting in scattered local populations in the southern portion of the Sacramento-San Joaquin River Delta (South Delta) (Williams et al. 2008). Since that time, riparian brush rabbits have been discovered in approximately nine other small South Delta remnant riparian patches (Williams and Hamilton 2002; Lloyd and Williams 2003; Hamilton 2010).

Recognizing the known population areas were small and isolated from other suitable habitat, USFWS initiated a controlled propagation program in 1999 in partnership with the Endangered Species Recovery Program of California State University Stanislaus and other partners (Williams et al. 2002). In 2001, captive-breeding began. The program trapped riparian brush rabbits in the South Delta and temporarily placed them in three large outdoor pens where offspring could be easily collected for translocation. Healthy young rabbits were released into suitable habitat on the Refuge adjacent to Caswell Park beginning in July 2002. By the time the captive propagation program concluded in December 2013, 1,496 rabbits had been released on the Refuge which now contains the largest extant local population of riparian brush rabbits as well as the largest area of suitable habitat (Kelly 2018).

ii. Current Range and Distribution

Currently, riparian brush rabbits are distributed in two broad regions (Figure 1). The largest is the population consisting of the offspring of translocated rabbits on the Refuge and the native

rabbits of the adjacent Caswell Park. This local population spans 15 km (9.3 mi.) in the riparian communities along the San Joaquin River from approximately 2.7 km (1.7 mi.) south of the confluence of the Tuolumne and San Joaquin Rivers to approximately 4 km (2.5 mi.) north of the confluence with the Stanislaus River, and spans approximately 7 km (4.2 mi.) east along the Stanislaus River. Suitable habitat in this area totals approximately 1,416 ha (3,500 ac.) of native and restored riparian habitat which is relatively contiguous (Eric Hopson pers. comm. 8/27/2019).

The other broad region consists of disjunct local populations scattered throughout the South Delta from approximately 2.7 km (1.7 mi.) south of the Interstate 5 Mossdale Bridge over the San Joaquin River northwest approximately 11 km (6.8 mi.) along Paradise Cut and north approximately 9 km (5.6 mi.) along the San Joaquin River. Genetic testing recently confirmed two rabbit carcasses discovered in 2017 along Middle River were riparian brush rabbits (Stephanie Prevost pers. comm. 10/22/2019). If a viable population is confirmed at this location it would expand the known occupied range several kilometers further north along the Middle River. As currently understood, the entire South Delta population area likely totals no more than a few hundred hectares (Williams et al. 2008).

B. Population Trend and Abundance

i. Historic Abundance

Wide-spread alteration of the native riparian forests in the San Joaquin Valley began in the mid-1800s, prior to any mammalogical surveys, and before a full description of brush rabbit subspecies was completed. The Department estimated the historic abundance of riparian brush rabbits by extrapolating William's (1993) local population density estimate from Caswell Park (3 rabbits/ha [3 rabbits/2.47 ac.]) to the estimated 36,700 ha (90,688 ac.) of riparian forest thought to exist along the San Joaquin River and its tributaries from its confluence with Merced River to just outside Stockton in pre-settlement times (Katibah 1984). Based on this information, it was estimated that as many as 10,000 individuals may have existed historically. Prior to the subspecies listing under CESA, local riparian brush rabbit populations were known to have crashed repeatedly during flood events. For example, floods in the spring of 1986 covered most of Caswell Park. The following summer, the only areas with evidence of regular riparian brush rabbit use totaled approximately 3.6 ha (8.9 ac.) (Williams 1988). At that time, the population was estimated to be 6-31 rabbits (Williams 1988).

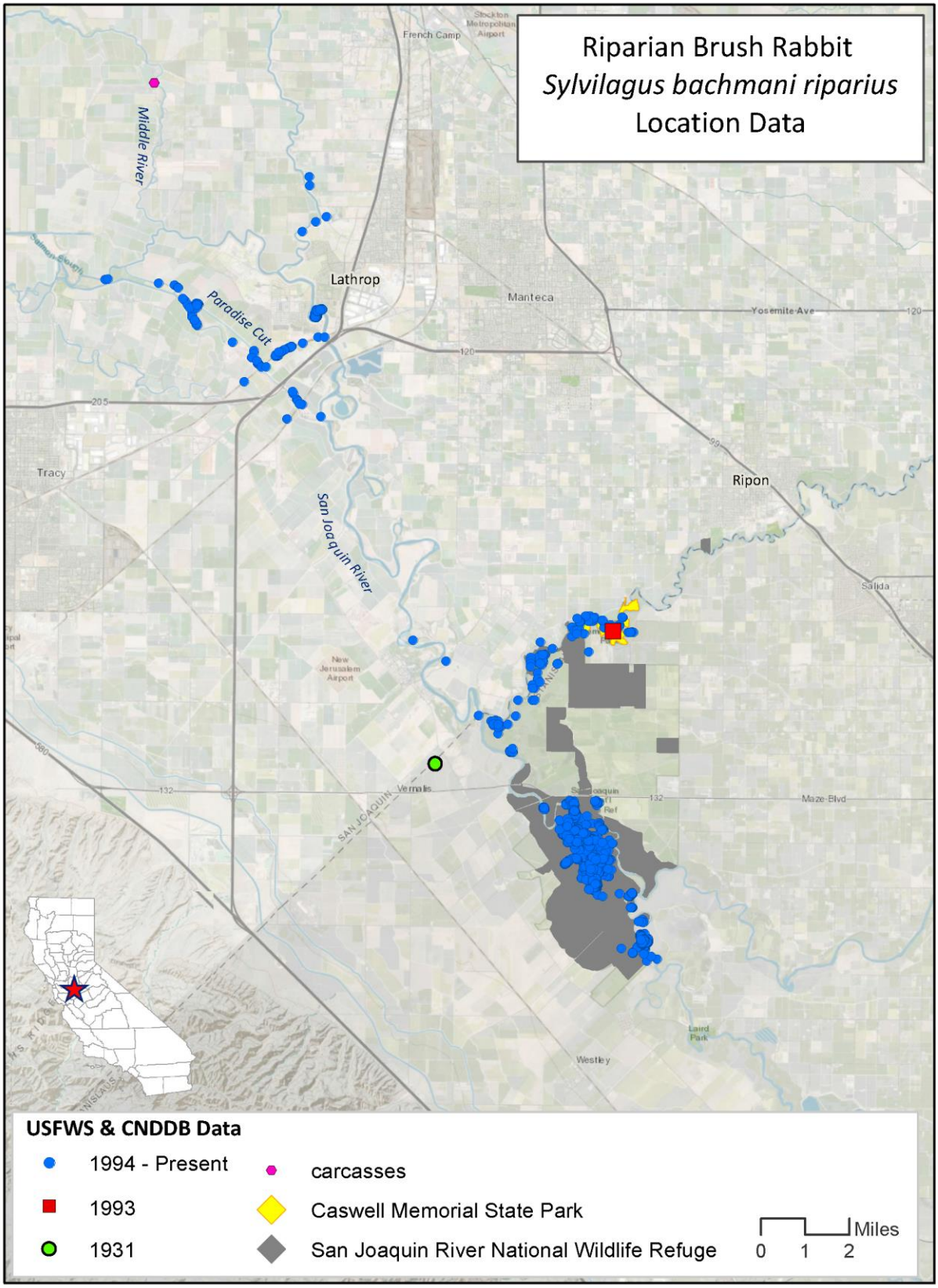

Figure 1. Distribution of riparian brush rabbit records.

ii. Current Populations

There are no contemporary estimates of the riparian brush rabbit population. In 1993, the last time the Caswell Park population was estimated, 43 individuals were captured resulting in a population estimate of 241 rabbits (Constable et al. 2011). Since that time, the number of animals trapped per effort in the Park has declined significantly, with the most recent efforts resulting in six trapped rabbits in 2005 and nine in 2006 (Constable et al. 2011). Elsholz (2010), anecdotally observed that riparian brush rabbits were common in his Caswell Park study areas from 2004-2005 but following a flood in 2006 rabbit sightings were “extremely rare”. In 2007 only four rabbits were observed on his 125 study sites. Caswell Park staff observed only one rabbit between 2008 and 2010 (Elsholz 2010). Annual rabbit surveys at Caswell have not been conducted since February 2008.

There has never been an attempt to census or estimate the size of the South Delta local populations. Approximately 238 riparian brush rabbits were trapped in the South Delta 1999-2010 as breeding stock for the captive propagation effort (Constable et al. 2011). Williams et al. (2008) believed populations in the South Delta totaled “at most a few hundred rabbits”. These small local populations have proven persistent. Williams et al. (2008) speculated that frequent disturbances from farming and flood control actions have maintained early successional riparian plant-communities in the South Delta which sustain riparian brush rabbits.

From 2002-2013 nearly 1,500 captive-bred riparian brush rabbits were released on the West Unit of the Refuge (Kelly 2018). Census trapping in 2005 captured a higher proportion of Refuge-born rabbits than translocated captive-bred individuals and resulted in a relatively high overall capture rate, indicating translocated captive-bred rabbits were effectively surviving long enough to reproduce on the Refuge (Kelly and Lloyd 2009). This early success was set back when the Refuge flooded during the spring and summer of 2006 and the newly established local population crashed. No rabbits were captured during census efforts on the Refuge in the fall 2006 and spring of 2007 (Ibid.). However, by the spring 2008 census, the capture rate of Refuge-born rabbits was again nearly equal to the capture rate of captive-bred rabbits, and from 2008-2010 each census captured more Refuge-born individuals than captive-bred individuals (Kelly and Lloyd 2010). High overall capture rates indicated the local population in the West Unit was well established; so further releases in the area were suspended. However, release of small numbers of captive-bred rabbits continued in other areas of the Refuge through 2013 (Kelly 2018).

Wittmer et al. (2016) used survival estimates and reproductive parameters derived from monitoring 325 translocated riparian brush rabbits released on the Refuge from 2002 to 2005 to model the viability of the local population. Several different scenarios were modeled, including continued translocations, suspended translocations, and different frequencies and severities of flood events. They found very high probabilities of local extinction under all examined scenarios, including scenarios that excluded flood events which suggested the local population was not self-sustaining. The authors noted, however, that the model results did not reconcile with observations of riparian brush rabbit persistence on the Refuge following the suspension of translocations and the persistence in the small South Delta and Caswell Park populations. This

disagreement suggests survivorship and reproduction rates in the established population on the Refuge were higher than the rates observed in translocated rabbits.

A significant flood event occurred in late March of 2011 and a salvage effort was initiated to rescue riparian brush rabbits from flooded and vulnerable areas and relocate them to higher ground (Kelly and Holt 2011). The fall 2011 census capture rate indicated the Refuge riparian brush rabbit population was dramatically reduced by the flood. A similar flood event occurred in 2017, again prompting salvage efforts by Endangered Species Recovery Program researchers and Refuge staff. Rabbit survival appears to have been higher through the 2017 flood compared to earlier floods. This was most likely due to the presence of newly constructed high elevation earthen mound refugia (popularly referred to as bunny mounds), efforts to plant vegetation on the upper slopes of levees to provide cover and forage for rabbits retreating from flooded lowlands, and the salvage and supplemental feeding of stranded rabbits by researchers and Refuge staff (Kelly 2018; Eric Hopson pers. comm. 8/27/2019). Increased survival through the flood event would be expected to facilitate more rapid population recovery following the flood. However, the regular census was suspended in 2013, so no data is available on the post-flood local population size, nor on the current population size and trend (Kelly 2018).

V. THREATS AND SURVIVAL FACTORS

A. Factors Affecting Ability to Survive and Reproduce

i. Present or Threatened Modification or Destruction of Habitat

The major cause of the decline in the riparian brush rabbit subspecies population is the loss, fragmentation, and degradation of San Joaquin Valley native riparian communities from their historic range (Williams and Basey 1986; Basey 1990). Intact San Joaquin Valley riparian forest has been reduced to <1% of its historical extent, primarily through the clearing of natural vegetation, irrigated cultivation, and the impoundment and channelization of rivers (Williams et al. 2008). Much of the remaining San Joaquin Valley riparian habitat is fragmented and regularly subjected to prolonged flooding, which limits the ability of riparian brush rabbits to occupy suitable habitat patches. In addition, riparian communities degraded by vegetation removal, fires, and invasive species are unlikely to support viable riparian brush rabbit populations due to modified cover, decreased forage availability, and increased predation pressure.

ii. Overexploitation

Hunting of riparian brush rabbits is prohibited by law; however, it is possible that riparian brush rabbits may be taken inadvertently on occasion by hunters pursuing desert cottontails. Riparian brush rabbits could also be taken by landowners attempting to control desert cottontails which damage crops and irrigation tubing. Finally, riparian brush rabbits can be killed or injured during handling related to research and captive propagation.

iii. Predation

Documented predators of brush rabbits include red-tailed hawk (*Buteo jamaicensis*), Cooper's hawk (*Accipiter cooperi*), barn owl (*Tyto alba*), great horned owl (*Bubo virginianus*), California scrub jay (*Aphelocoma californica*), bobcat (*Felis rufus*), coyote, raccoon (*Procyon lotor*), gray fox (*Urocyon cinereoargenteus*), striped skunk (*Mephitis mephitis*), mink (*Neovison vison*), long-tailed weasel, western rattlesnake (*Crotalus viridus*), and gopher snake (*Pituophis catenifer*) (Bryant 1918; Foster 1927; Hall 1927; Orr 1940; Sumner 1929 as summarized in Basey 1990). Non-native predators include black rats (*Rattus rattus*), feral cats, and feral dogs (Williams 1988; Patrick Kelly pers. comm. 8/28/2019).

iv. Competition

The only significant competitor with riparian brush rabbits for food resources are desert cottontails, which are sympatric (occur in the same areas) with riparian brush rabbits throughout most of the riparian brush rabbit's range (Basey 1990).

v. Disease

Riparian brush rabbits are subject to the common rabbit diseases that occur in California (Williams 1988), such as tularemia, plague, myxomatosis, silverwater virus, encephalitis, listeriosis, Q-fever, and brucellosis. In the captive riparian brush rabbit population, the most commonly implicated fatal disease was *Baylisascaris* spp. (a parasitic roundworm that infests the intestines and nervous system). Other diseases implicated in rabbit deaths were necrotizing typhlitis (inflammation and necrosis in the lower intestinal tract), and intestinal lymphoma (Williams 2008).

vi. Small Populations

The extant riparian brush rabbit subspecies population is small and exists in several small patches of suitable habitat isolated from each other. Small, isolated local populations are inherently vulnerable to extinction due to the loss of genetic variability, inbreeding depression, genetic drift, reduced genetic capacity to respond to changes in the environment, and demographic stochasticity (changes in age and sex ratios resulting in less than optimal breeding opportunities) from random variation in birth and death rates (Primack 1993; Reed and Frankham 2003). Additionally, the smaller the population size, the more likely it is that any of the threats acting on it alone or in combination will drive the population to extinction (Primack 2010).

vii. Flooding

Riparian brush rabbits, being dependent on riparian habitat, are vulnerable to flooding. In the last few decades, the lower San Joaquin River and South Delta have experienced major floods in 1995-1996, 1996-1997, 1998, 2005, 2006, 2011 and 2017. Because elevated land is extremely limited within the extant range of the riparian brush rabbit, floods result in numerous drownings. Rabbits that are able to climb vegetation above flood level or find refuge on levees

and other high ground are subjected to increased predation pressure and often starve due to limited forage (Williams and Basey 1986; Williams 1988; Basey 1990).

viii. Wildfire

Due to the extremely limited remaining amount of suitable riparian shrub and riparian forest habitat, wildfires occurring within the remaining habitat can cause direct mortality and easily destroy a large proportion of the remaining habitat (Williams and Basey 1986; Williams 1988; Basey 1990; Williams 1993).

ix. Invasive Species

Several known invasive plant species have been documented on the Refuge and likely occur elsewhere along the San Joaquin River and in the South Delta. These species include wisteria (*Wisteria* sp.), tree of heaven (*Ailanthus altissima*), giant reed (*Arundo donax*), pampas grass (*Cortaderia selloana*), tamarisk (*Tamarix* sp.), and edible fig (*Ficus carica*). Changes in the vegetative community imposed by invasive species may render habitat less suitable for riparian brush rabbits by reducing available forage and cover (USFW 2014).

x. Rodenticides

Riparian brush rabbits outside of the Refuge and Caswell Park may be exposed to rodenticides that can kill individuals and potentially limit range expansion.

xi. Recreation

Riparian brush rabbits, primarily within Caswell Park, likely experience disturbance due to the presence of recreating humans and may be impacted by land management practices such as campground clearing, fuel treatments, and trail maintenance that adversely modify habitat.

xii. Climate Change

Anthropogenic changes in climate will likely impact riparian brush rabbits chiefly through changes in the San Joaquin Basin hydrologic regime. Climate projections indicate the frequency and severity of flood events will increase in coming decades (Das et al. 2013). This factor is discussed further under section V.vii. Climate change is also likely to result in more frequent droughts and droughts of longer duration (He et al. 2018). Droughts could impact riparian brush rabbits by causing compositional and structural changes in the vegetative communities they rely upon and increasing the frequency and severity of wildfires (Westerling and Bryant 2006; Bedsworth et al. 2018). In addition, projected temperature increases could result in lethal heat stress (Hinds 1973).

B. Degree and Immediacy of Threats

i. Present or Threatened Modification or Destruction of Habitat

Riparian forest communities in the San Joaquin Valley have been reduced to <1% of their historical extent, primarily through the conversion of native communities to agricultural production and impoundment and channelization of streams and rivers (Williams et al. 2008). These changes were made possible by the construction of dams on tributary rivers (e.g. New Exchequer Dam on the Merced River [completed 1967], New Melones Dam on the Stanislaus River [completed 1978], and New Don Pedro Dam on the Tuolumne River [completed 1971]), which collectively reduced the frequency and severity of flooding in the San Joaquin Valley. The construction of reservoirs and flood control levees allowed farmers to clear, level, and cultivate San Joaquin Valley floodplains and adjacent shrublands (Williams and Basey 1986). Prior to large-scale land conversion, many valley riparian zones had uneven topography with adjacent shrub-covered uplands elevated above typical flood levels that provided refuge to riparian brush rabbits during flood events (Williams and Basey 1986). These elevated shrubland rabbit refuge areas no longer exist. High ground is now primarily limited to levee tops that provide little cover from predators and limited forage (Williams and Basey 1986).

The Refuge and Caswell Park population is not at risk of further habitat loss from agricultural, commercial, or residential conversion; however, the majority of the Refuge was cleared, leveled, and farmed prior to being acquired by the USFWS and therefore provides few elevated areas for rabbits outside of levees and constructed flood refugia (i.e. bunny mounds).

South Delta local populations are at risk of further habitat fragmentation and destruction as they occur largely on privately owned lands (Williams et al. 2008). Large-scale residential and commercial development projects have recently been approved in this area. The Mossdale Village, Central Lathrop, and River Islands at Lathrop Specific Plan Areas in the City of Lathrop allow for the development of approximately 3,035 ha (7,500 ac.) in the South Delta (City of Lathrop 2019), (Figure 2). The largest of these Specific Plans is the River Islands at Lathrop, roughly bounded by Interstate 5, the San Joaquin River, Old River, and Paradise Cut. The City of Lathrop is a signatory to the San Joaquin County Multi-Species Habitat Conservation and Open Space Plan, which requires the complete avoidance of occupied riparian brush rabbit habitat. However, development in this area near the juncture of several local South Delta populations further fragments already isolated remaining occupied habitat. Loss of habitat in this rapidly developing area also significantly impacts the conservation and recovery of the subspecies because local populations in this area are more flood-secure than populations elsewhere (see Figure 4). Although occupied habitat is protected under the Habitat Conservation Plan, local riparian brush rabbits will be subject to the impacts associated with nearby residential development (e.g. human trespass into occupied habitat, predation by domestic dogs and cats and non-native rats, nighttime lighting, and potentially more frequent fire ignitions resulting in habitat degradation and loss [Syphard et al. 2007; Kelly 2018]). Residential and commercial development in the area occupied by South Delta riparian brush rabbit populations effectively precludes future habitat restoration opportunities within the development footprint.

In the same general location, a major flood control project is under consideration. The Paradise Cut Flood Management Project is in the planning stages (Figure 3). This project would expand the flood zone west of Paradise Cut and install a 305 m (1,000 ft.) weir at the junction of Paradise Cut and the San Joaquin River to allow water managers to open the floodway during flood events. The project is projected to result in a 0.6 m (2 ft.) reduction in peak flood stage in the lower San Joaquin River (California Department of Water Resources 2017). This reduction in peak flood elevation may benefit riparian brush rabbit populations locally and upstream by increasing the area of dry refugia during floods and slightly shortening the duration of flood events. The project concept also includes the creation of 202 ha (500 ac.) of riparian scrub and wetland habitat which could provide some benefit to local riparian brush rabbit populations. However, the new habitat would be subject to periodic flooding and therefore is unlikely to contribute to recovery of the subspecies. The planned flood bypass area includes the locations where the majority of the breeding stock used in the captive propagation project were captured (Kim Forrest pers. comm. 9/20/2019).

Another less common but potentially significant source of habitat loss is from illegal marijuana grows. Illegal grows were found in riparian habitats at the captive propagation pens in San Joaquin County and have been found within the Refuge in the past (USFWS 2006; Kelly 2018). The degree of threat posed by this activity is unknown.

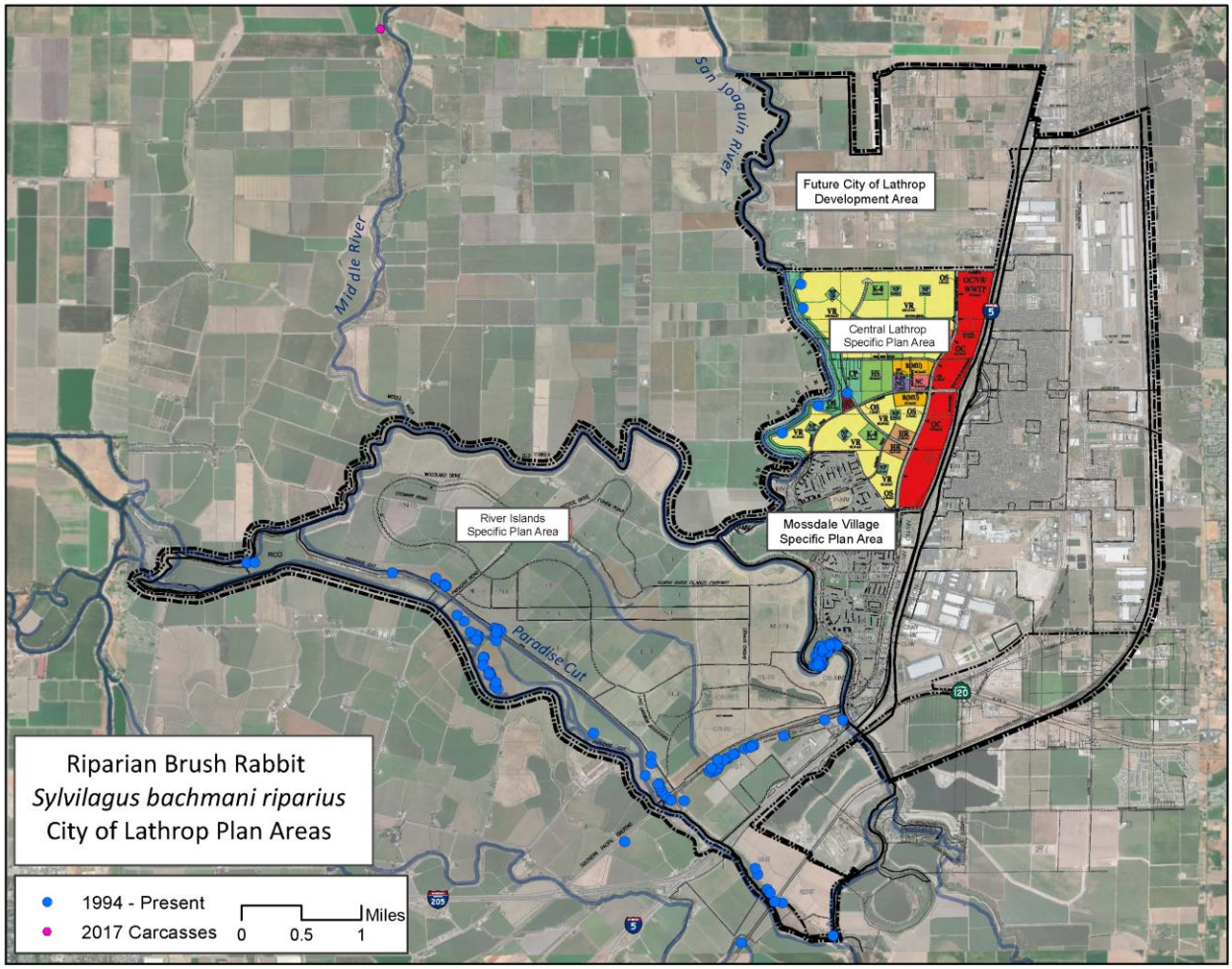

Figure 2. City of Lathrop planned development areas.

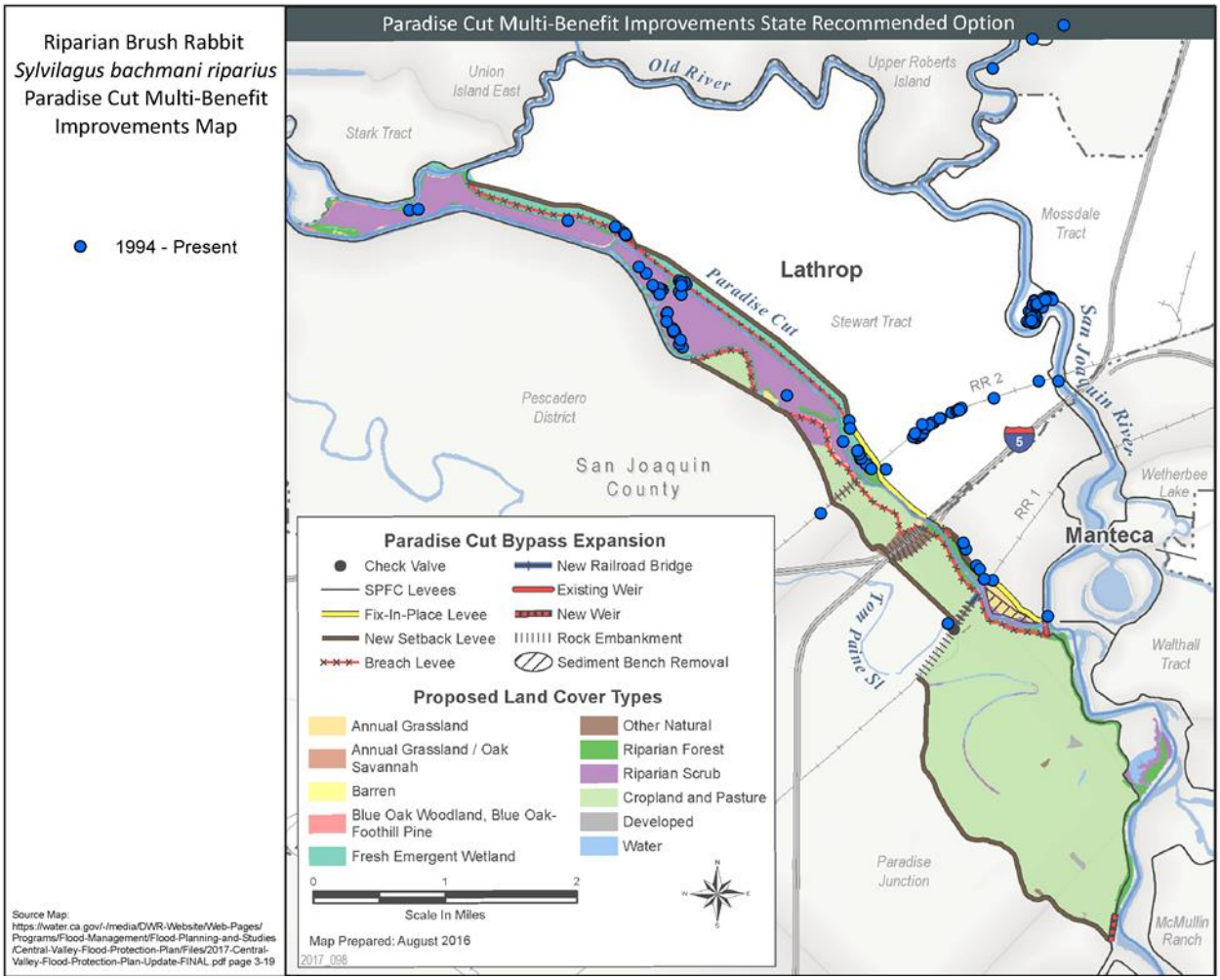

Figure 3. Proposed Paradise Cut Flood Management Project.

ii. Overexploitation

As a CESA-listed species, the hunting of riparian brush rabbits is prohibited (Fish and G. Code § 2080), and approximately half of the South Delta local population area lies within a rabbit hunting closed zone which was designated in 2002 to protect the known occurrences of riparian brush rabbits outside of Caswell Park as they were understood at that time (Cal. Code Regs. tit.14 § 308(d)). Additionally, all hunting is prohibited in Caswell Park, the 12 ha (30 ac.) Oxbow Preserve in Lathrop, and all rabbit hunting is prohibited on the Refuge. Nonetheless, it is possible that hunters occasionally mistakenly take endangered riparian brush rabbits when pursuing legally huntable rabbit species outside of areas closed to hunting. Since 2002, additional small local populations of riparian brush rabbits were discovered north and south of the closure zone in areas open to rabbit hunting. However, the Department Wildlife Officers who collectively patrol the entire occupied riparian brush rabbit range in San Joaquin and Stanislaus Counties reported they rarely observe rabbit hunting in the two counties, nor had they ever encountered hunters in pursuit of riparian brush rabbits (Warden Adam Cahn, Capt. Ryan Detrick, Warden Jeffrey Moran, Lt. Eric Vielhauer pers. comm. 6/17/2019).

Take of cottontail rabbits is known to occasionally occur in San Joaquin County to curtail the destruction of drip irrigation lines in vineyards (Capt. Eric Vielhauer, pers. comm. 6/17/2019). It is possible that endangered riparian brush rabbits could be mistakenly taken when landowners are controlling destructive cottontails. However, with the exception of the margins of vineyards adjacent to riparian habitat, riparian brush rabbits would be unlikely to venture into vineyards due to their lack of dense shrubby cover. Therefore, the accidental take of riparian brush rabbits is most likely minimal.

Researchers are required to report take of riparian brush rabbits to the Department as a condition of the Memoranda of Understanding to handle the subspecies. The Department was notified of several mortalities related to the captive propagation and translocation effort. Most of the reported mortalities resulted from trauma sustained in traps. A few animals also succumbed to radio-collar related trauma, and others from unknown trauma. Since the captive propagation and translocation effort concluded in 2013, no additional research-related take has been reported to the Department. Currently only two researchers are permitted by the Department to handle riparian brush rabbits, and no active research efforts are underway. At this time, overexploitation does not pose a significant threat to the subspecies population.

iii. Predation

Predation is the primary cause of mortality in many rabbit and hare species and was identified as the cause of most attributable mortalities in released captive-bred riparian brush rabbits on the Refuge (Williams et al. 2008; Hamilton 2010). Riparian brush rabbits are known to be preyed upon by a wide variety of avian, mammalian, and reptilian predators (see Predation section above). Predation in unaltered natural systems is unlikely to result in prey extinction (Krebs et al. 1995); however, when the prey species' environment is altered abruptly or systematically at a rate above normal background change (e.g. the dramatic reduction in San Joaquin Valley riparian forests), increased predation may drive populations to extinction (Sodhi et al. 2009).

Predation rates on riparian brush rabbits near Caswell Park are believed to be high due to the presence of feral cats and black rats. Black rats are thought to be significant predators of newborn rabbits in nests (Williams et al. 2002; Patrick Kelly pers. comm, 8/28/2019). The USFWS (2000) concluded that any predation on small, isolated riparian brush rabbit populations was a significant threat to the subspecies population.

Although little is known about local riparian brush rabbit populations in the South Delta, Williams et al. (2002) believed feral cats, long-tailed weasels, and coyotes were likely the most abundant predators in the area. Kelly et al. (2011) noted that predation risk in the South Delta was elevated in many areas due to adjacent residential properties supporting cats, rats, and dogs, as well as the existence of roads and waterways, which provide easy access to predators.

Predation throughout the occupied range is elevated during the frequent flood events that impact the San Joaquin Valley. When rabbits seek refuge from floodwaters in trees and on the limited areas of levee tops and constructed bunny mounds they are subject to extreme predation pressure because they are concentrated in small areas which often lack the dense

shrub, and tree cover that brush rabbits normally seek for protection from predators. Researchers and Refuge staff have observed coyotes swimming to flood refugia during flood events to prey on stranded rabbits (Eric Hopson pers. comm. 8/27/2019; Patrick Kelly pers. comm. 8/28/2019). Over the course of a prolonged flood event in 2017, Refuge staff monitored rabbits (a mix of desert cottontails and riparian brush rabbits) stranded on the upper portions of a 3.2 km (2 mi.) long levee. The monitored population declined from 487 rabbits observed in March to less than 100 in July when flood waters had receded enough to allow stranded rabbits to disperse. The dramatic population decline was most likely due to a combination of predation and starvation (Katherine Heffernan pers. comm. 6/4/2019).

Riparian brush rabbits face high predation rates from native predators as well as potentially significant additional predation pressure from introduced predators such as feral cats, dogs, and black rats that are supported by residential development (Williams 1988; Basey 1990; Kelly et al. 2011; Kelly 2018). Habitat fragmentation has likely created more favorable conditions for generalist predators such as coyotes to gain access to riparian brush rabbits. The limited availability of flood-safe habitat compounds predation pressure by concentrating rabbit populations in small areas that lack adequate cover during flood events. Predation significantly threatens the survival and recovery of the riparian brush rabbit subspecies population.

iv. Competition

Riparian brush rabbits are sympatric (co-occur) with desert cottontails throughout their range, except possibly within the mature riparian forests in the interior of Caswell Park (Basey 1990). Both species are found associated with riverside brush thickets and forage on the same types of plants (Ingles 1965); however, desert cottontails can also be found in a broad range of habitats far from rivers: dense grass, hedge rows, rock piles, and man-made structures (Basey 1990). Desert cottontails also move further from cover when foraging, have larger home ranges, and have greater fecundity than riparian brush rabbits (Dixon et al. 1981; Chapman et. al. 1982). Interestingly, a lower proportion of desert cottontails appear to survive long-term stranding on small patches of dry land during major flood events compared to riparian brush rabbits (Kim Forrest pers. comm. 9/20/2019). However, due to their use of a wider range of habitats, longer movements, and greater fecundity, desert cottontails are more able to survive when displaced from riparian habitat by floods and fires, and are able to rapidly recolonize recently flooded or burned habitat (Basey 1990). In the altered and fragmented riparian habitat remaining in the San Joaquin Valley and Delta, competition from desert cottontails may pose a significant challenge to the persistence of riparian brush rabbits (Williams and Basey 1986; Basey 1990).

v. Disease

Brush rabbits are subject to common rabbit diseases in California (Williams 1988), such as tularemia, plague, myxomatosis, silverwater virus, encephalitis, listeriosis, Q-fever, and brucellosis; some of which can reach epidemic proportions (Chapman 1974, Williams 1988, Williams et al. 2002). Of these, the bacterial disease tularemia has the greatest potential to negatively impact riparian brush rabbits at the population level. Tularemia has been implicated in population regulation of the closely related eastern cottontail (*S. floridanus*) and is known to

be endemic in brush rabbit populations (Woolf et al. 1993; Williams et al. 2002). Although tularemia is typically enzootic in rabbit populations (i.e. present, but effecting only a small proportion of the population at a given time), it occasionally becomes epizootic (rapidly spreads through a population in an outbreak) and can cause drastic die offs in rabbit populations (Woolf et al. 1993). Tularemia is frequently fatal, and it is thought to be the most frequent cause of cottontail mortality with the exception of predation. Isolated populations are at greater risk of severe population declines from tularemia epizootics than large contiguous populations (Woolf et al. 1993). Tularemia is transmitted through contact with infected tissue, ingestion of aerosolized particles, and contact with infected soil or water. It can infect most vertebrate species. Riparian brush rabbits could easily be exposed to the bacterium through contact with infected desert cottontails or other sympatric species (USFWS 2000). It is of additional concern because it is a known zoonotic (transmissible to humans), (Williams et al. 2002).

Myxomatosis is a mildly pathogenic viral disease which is endemic in California brush rabbit populations and is known to have become epizootic in California brush rabbits from the San Francisco Bay to Baja California, Mexico in the 1960s. More than 95% of a brush rabbit population in southern California was found to be infected by the virus, although mortality rates were low (Regnery and Miller 1971).

In the captive riparian brush rabbit population, the most commonly implicated fatal disease was *Baylisascaris* spp. infection (a parasitic roundworm which infests the intestines and nervous system). *Baylisascaris* spp. roundworms are spread through eggs in the feces of infected racoons and skunks and ingested by rabbits (and other vertebrate hosts, including humans). Once ingested, eggs hatch and some larvae migrate to the host's central nervous system and cause debilitation and death (Gavin et al. 2005). Other diseases implicated in rabbit deaths were necrotizing typhlitis (inflammation and necrosis in the lower intestinal tract), and intestinal lymphoma (Williams 2008). The captive propagation and reintroduction program did not identify infectious disease problems in the source population, captive rabbits, or reintroduced riparian brush rabbits as a significant source of mortality (Gilardi et al. 2004). However, if exposure to infected desert cottontails or other species were to result in tularemia epidemics in the small, isolated, riparian brush rabbit populations, rapid extirpations (local extinctions) could occur (Williams 1988).

vi. Small Populations

No recent estimates of the riparian brush rabbit subspecies population exist. However, the population size is undoubtedly so small that genetic and environmental factors present significant threats to its viability. As recently as 1993, the total population was estimated at 241 animals, although at that time only the Caswell Park population was known (Constable et al. 2011). Since then, additional small local populations have been discovered in the South Delta and over 1,500 riparian brush rabbits were released over a period of 11 years on the Refuge; however, their fates and the fates of their offspring are largely unknown and there have been significant flood events since their release (Kelly 2018). Likely no more than a few thousand riparian brush rabbits exist today in fragmented populations that remain vulnerable to periodic crashes during flood events (Constable 2011).

Random fluctuations pose risk to small populations due to demographic stochasticity (random variation in sex ratios, reproductive output, and survival amongst individuals from year to year). In small populations, this variation can cause the population size to fluctuate randomly up or down (Primack 1993). The smaller the population size, the more pronounced the effect. Once a population size drops, its next generation is even more susceptible to further stochasticity and random inequalities in the sex ratio, resulting in fewer mating opportunities and a declining birth rate (Primack 1993). Due to their small population sizes (particularly following flood events), riparian brush rabbits are likely vulnerable to these effects.

Unpredictable changes in the natural environment and biological communities can cause the size of small populations to vary dramatically, whereas larger, more widely distributed populations remain more stable because such changes normally effect only a small proportion of the population (Primack 1993). For example, unpredictable local changes in a species' food resources or predator populations, climate, vegetative community, or disease and parasite exposure can cause the size of a small, isolated population to fluctuate wildly, and possibly lead to extinction (Primack 1993). Additionally, natural disasters such as droughts, fires, and floods can lead to dramatic population changes if the population is small and localized such that the disaster impacts all or most of the individuals.

The loss of genetic diversity inherent to small, isolated populations can be expected to increase their risk of extinction as small, inbred populations have reduced genetic capacity to adapt to changing environments (Frankham 2005). In populations with a limited breeding pool, genetic drift (the variation in the relative frequency of different alleles in the population due to the chance disappearance of particular alleles from inbreeding and lack of immigrants) becomes likely (Hedrick and Kalinowski 2000). In large populations, maladaptive genes do not accumulate in the population since random mate pairings are frequent and less fit offspring survive and reproduce less frequently through natural selection. However, in small, isolated populations natural selection can have less of an effect on the population genotype than genetic drift. When this happens, deleterious alleles can become fixed in the population, resulting in inbreeding depression (decreased reproductive fitness in all individuals), and potentially negative population growth (Hedrick and Kalinowski 2000; Frankham 2005).

The loss of genetic diversity and the accumulation of deleterious alleles can largely be mitigated by the exchange of breeding individuals between population centers (Primack 1993). When individuals disperse from their natal population to new population areas, the novel alleles they introduce can balance the effects of genetic drift and inbreeding depression. As few as one migrant per generation in a population of 120 individuals can negate the effects of genetic drift (Primack 2010). Consequently, habitat fragmentation can seriously increase the genetic risks to isolated local populations, and habitat connectivity between local populations can substantially mitigate these risks.

Two studies of microsatellite DNA markers concluded that the South Delta local riparian brush rabbit population is genetically distinct from the Caswell Park local population. The studies found greater genetic diversity in the South Delta population, likely due to recent genetic bottlenecks (severe population crashes) in the Caswell population (Williams et al. 2002;

Constable et al. 2011). More recent mitochondrial DNA sequencing, microsatellite analysis, and single nucleotide polymorphism analysis by Matocq et al. (2017) further elucidated genetic relationships between riparian brush rabbit local populations. This analysis confirmed significant genetic structure (differences in allele frequencies between populations) between the Caswell Park local population and the South Delta local population. The genetic differentiation between populations was found to be significant, only slightly less than that found between the riparian brush rabbit and *S. bachmani macrorhinus,* a subspecies of the California Coast Range. This indicates geographic distance and barriers to rabbit movement between Caswell Park and the South Delta have likely limited contemporary gene flow between the two local population groups (Matocq et al. 2017). It appears the isolated populations differentiated through the effects of genetic drift (Rippert 2017). Within the South Delta populations, Matocq et al. (2017) also detected genetic differentiation between rabbits on the west side of the Delta along Paradise Cut and rabbits to the east near Mossdale, suggesting discontinuous habitat between the two areas.

The genetic composition of the introduced riparian brush rabbit population on the Refuge is intermediate to the South Delta and Caswell Park local populations, indicating gene flow between the Refuge rabbits of South Delta parentage and the native rabbits of Caswell or other undocumented local native populations (Matocq et al. 2017; Rippert 2017). This genetic exchange, facilitated by restored habitat connections, suggests continued recovery and restoration efforts are likely the best option for management and recovery of this subspecies. (Rippert 2017).

A variety of threats inherent to small populations may threaten riparian brush rabbits. Environmental and genetic effects can work in concert to amplify other threats. As populations get smaller, they become more vulnerable to demographic variation, environmental variations, genetic drift, and inbreeding depression. Each of these effects can amplify the impact of the other effects, further reducing population size and accelerating the species towards extinction in what has been termed an extinction vortex (Primack 1993).

vii. Flooding

The entire riparian brush rabbit subspecies population is at risk of periodic flood events, with nearly all known occurrences within a projected 100-year flood zone mapped by the Federal Emergency Management Agency in its National Flood Hazard Layer (Figure 4).

The San Joaquin River and its tributary rivers are regulated by a series of flood control and irrigation storage dams that prevent flooding in typical water years. Occasionally however, atmospheric river rainfall events or periods of rapid snowmelt (often in combination) overwhelm the system and reservoir operators must release flood-level flows resulting in prolonged flood events (Phillip Williams and Associates 2001). Floods have occurred on the lower San Joaquin River in 1950-51, 1952, 1955-56, 1962-63, 1976, 1982-83, 1985-86, 1995, 1996-1997, 1998, 2005, 2006, 2011, and 2017 (Williams 1988; Hamilton 2010; Kelly 2018).

Climate projections indicate flooding will become more frequent and more severe with warming temperatures. The frequency of extreme precipitation atmospheric river events is projected to

increase nearly three-fold and the amount of precipitation delivered during extreme storm events projected to increase by 15%-39% by the end of the century (Warner et al. 2014).

Das et al. (2013) evaluated an ensemble of 16 global climate models under two future emissions scenarios and found an increased flood risk in central Sierra Nevada rivers (e.g. Stanislaus, Tuolumne, and Merced Rivers, which are tributary to the lower San Joaquin River and Delta) in a large majority of the projections. The projected increases in flood intensity and frequency are attributed to stronger storm intensities and warmer temperatures resulting in more precipitation falling as rain, which runs off rapidly, rather than snow which accumulates and melts gradually.

In the San Joaquin River watershed, the magnitude of 50-year peak flow flood events is projected to increase by 50-100% to levels that exceed current flood infrastructure design standards (Das et al. 2013). These changes in flow magnitude are projected to progressively increase through the next century with significant increases realized by 2025-2035. These changes will challenge California's reservoir managers who strive to balance flood control with irrigation storage, likely resulting in more frequent and intense flood flows released to the lower San Joaquin River (Das et al. 2013).

Floods can drown riparian brush rabbits, concentrate rabbits in small areas above floodwaters, such as levee tops and man-made bunny mounds where they are vulnerable to predators and starvation for several months until floodwaters recede. Floods can also damage riparian habitat by scouring vegetative cover and forage plants, and killing vegetation intolerant of prolonged inundation such as coyote bush (*Baccharis pilularis*), blue elderberry, wild rose, and California blackberry (Singleton et al. 2007). Post-flood surveys conducted in Caswell Park and the Refuge indicate high levels of brush rabbit mortality occur during floods. A flood event in the spring of 2006 inundated much of the Refuge under 1-3 m (3.3-9.8 ft.) of water for up to 17 weeks, resulting in the deaths of 91% of radio-collared rabbits (Lloyd et al. 2011). Regular flood events along the San Joaquin River have resulted in repeated drastic population declines. For example, in 1976 the Caswell Park population was reported to number less than 20 individuals following that year's flood event (CDFG 1993), and after the next severe flood in the winter of 1985-1986, Williams (1988) estimated only 6 to 31 individuals remained.

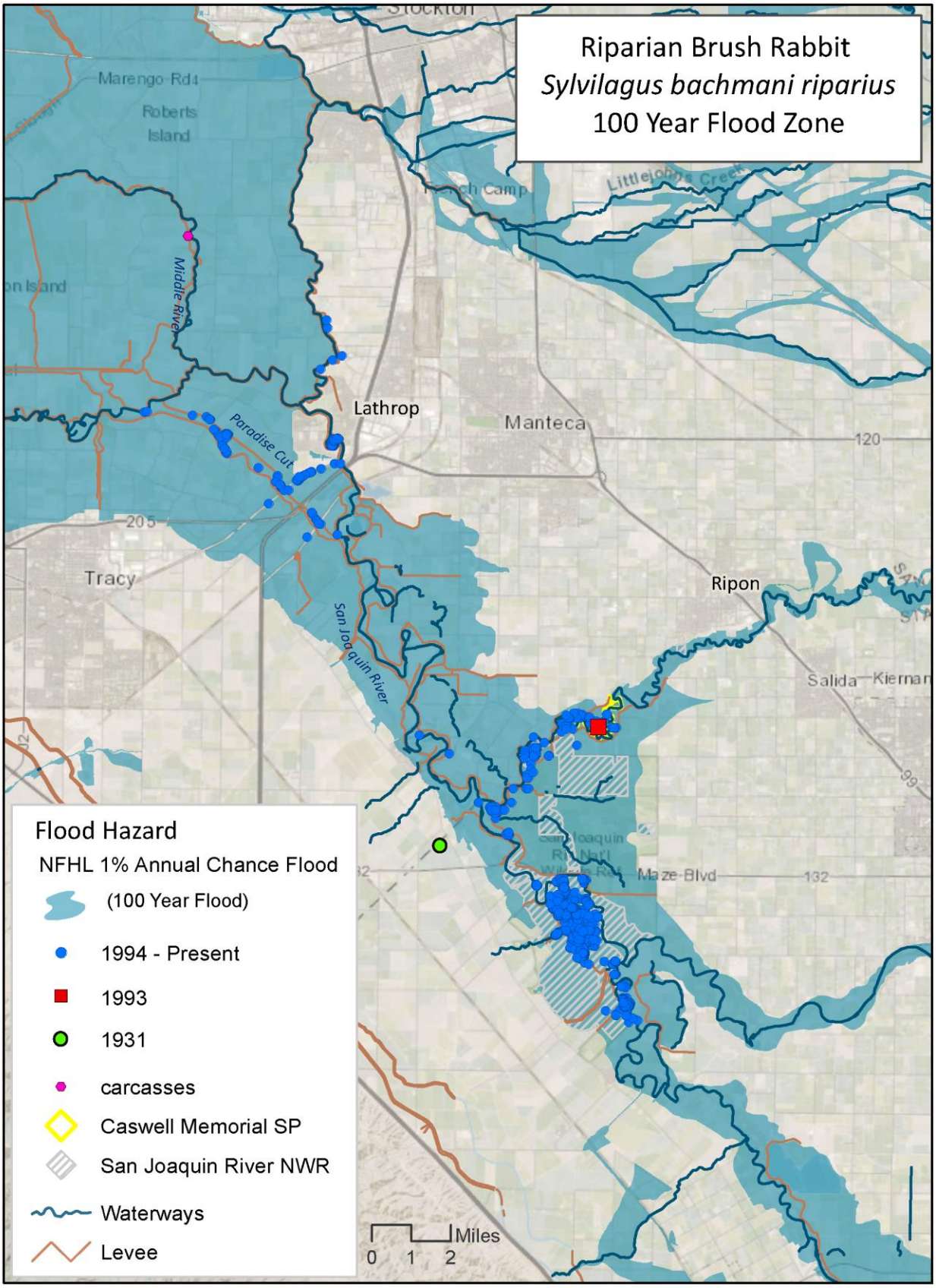

Figure 4. Federal Emergency Management Agency 100-year flood hazard zone.

Following the catastrophic flood of 2006, Refuge staff constructed several earthen mounds (bunny mounds) and planted the mounds and the tops of levees with riparian shrub and tree species to create flood refugia for riparian brush rabbits (Lloyd et al. 2011) (Figure 5). During a subsequent flood of similar magnitude in 2011 riparian brush rabbits were observed using the bunny mounds and vegetated levees. Approximately 50% of brush rabbits appeared to survive the event, suggesting the additional high elevation habitat was beneficial (Kelly and Holt 2011). However, bunny mounds and levees alone do not provide enough forage and cover from predators to support high numbers of riparian brush rabbits through prolonged flood events. Refuge staff and researchers have repeatedly resorted to rescuing individual stranded rabbits by boat and feeding stranded rabbits to keep them alive through flood events (Eric Hopson pers. comm. 8/27/2019; Patrick Kelly pers. comm. 8/28/2019). Riparian brush rabbit managers and researchers do not believe bunny mound and levee refugia alone are adequate to ensure the long-term persistence of the subspecies on the Refuge. Much larger patches of high elevation flood refugia with adequate cover and food resources to sustain a substantial number of rabbits through prolonged flood events are needed (Eric Hopson pers. comm. 8/27/2019; Patrick Kelly pers. comm. 8/28/2019; K. Forrest pers. comm. 9/20/2019).

Little is known about the impact of flooding on riparian brush rabbits in the South Delta. While much of the remaining riparian habitat along levees and river channels is periodically inundated, limited areas of occupied habitat along railroad rights of way generally remain above floodwaters (P. Kelly pers. comm. 8/28/2019). As continuing residential development and flood control infrastructure development further isolate and restrict access to flood refugia in the face of projected flood events of greater magnitude and frequency, flooding will likely pose a serious threat to the South Delta local populations in the coming decades.

Recovery of the riparian brush rabbit will require several self-sustaining viable populations to exist in flood-secure areas. These areas must provide high quality refuge during flood events, including adequate forage to sustain stranded rabbits for several months at a time, as well as adequate cover from predators. Flood refuge areas must be secure from flood events which are projected to increase in magnitude and duration compared to the current flood regime. Until such conditions exist, the subspecies population will likely continue to repeatedly crash during catastrophic flood events, slowly rebuild, and crash again during the next flood. Following population crashes, the risk of extirpation from all threats is elevated. The riparian brush rabbit subspecies population, as distributed today, remains at risk of extinction from a single catastrophic flood event.

Figure 5. Portion of the San Joaquin River National Wildlife Refuge during 2011 flood showing bunny mound and levee refugia.

viii. Wildfire

Wildfires pose a serious threat to the riparian brush rabbit subspecies population through both direct mortality and through the destruction and modification of brush rabbit habitat (Williams 1988, Kelly 2018). Apart from the Refuge, remaining habitat patches are small and isolated, exposing riparian brush rabbits fleeing from fires to great risk of predation and starvation.

Wildfires occur regularly within the range of riparian brush rabbits. Prior owners of lands now part of the Refuge reported regular occurrence of wildfires, with approximately one fire every ten years (USFWS 2006). Between 1975 and 1987, ten small wildfires were reported within Caswell Park (Williams 1988). Recent large fires on the Refuge included the 607 ha (1,500 ac.) Pelican Fire in 2004 which burned approximately 58% of the Refuge, including 300 ac. of highly suitable riparian brush rabbit habitat; and the 235 ha (580 ac.) River Fire in 2008 (Phillips et al. 2005, Kelly 2018) (Figure 6). The area burned by wildfires, the number of large fires, and the length of the wildfire season have all increased in the western U.S. over the last half century. These changes were largely attributable to anthropogenic climate change (Abatzoglou and Williams 2016). These trends are expected to continue in the coming decades and wildfire is likely to frequently impact riparian brush rabbit populations.

Wildfires appear to result in limited rabbit injuries and deaths. Hamilton et al. (2010) found only three fire-related mortalities and few injured rabbits following the 2004 Pelican fire. The home range size of riparian brush rabbits under study by Hamilton et al. (2010) did not change significantly following the fire, although it should be noted that only 34% of the dense riparian habitat in the study area burned. In the year following the Pelican Fire, Kelt et al. (2014) noted high mortality rates near the burned area, although they could not identify a fire-related cause. An increase in high-severity wildfires would likely result in a far greater impact on surviving

rabbits due to removal of cover and forage which would expose them to increased predation and starvation. Long-term fire-related impacts on riparian brush rabbit habitat vary.

Woody plants burned in the Pelican Fire resprouted the following growing season and within a few years many areas had largely returned to structural and species composition conditions similar to what existed before the fire (River Partners 2006). Spring monitoring following a 2008 wildfire found basal sprouting from burned willows and shrubs as well as low levels of valley oak mortality, although treetops and shrubs had significantly died back (River Partners 2009).

To reduce wildfire threat, land managers attempt to reduce fuel loads through vegetation management. Unfortunately, areas of dense vegetation most vulnerable to fire are particularly important habitat for brush rabbits (Williams 1988). For example, much of Caswell Park is overgrown with decadent shrubs and forest floors contain large quantities of woody litter, creating a dangerous fuel load and increasing the likelihood of high severity wildfires (Williams 1988). When Park managers cleared brush and litter to reduce fire threat, riparian brush rabbits ceased use of the cleared areas (Williams 1988). Despite such fire prevention efforts, a dense understory of shrubs, a layered tree canopy and accumulated leaf litter remains in much of the Park, putting it at risk of catastrophic wildfire. The surrounding intensively farmed row crops offer little cover for escaping rabbits in the event of a large fire.

The threat of a large, catastrophic wildfire on the Refuge is partially attenuated by the presence of Refuge firefighting staff, the support of mutual aid firefighting agencies, and the presence of fuel breaks (Kelly 2018). Restored suitable habitat patches on the Refuge are generally larger and better connected with other areas of suitable habitat compared to the remaining habitat patches in the South Delta and Caswell Park. This connectivity on the Refuge should allow rabbits fleeing fires access to suitable cover and increase survival rates.

The fragmented nature of the remaining habitat in the South Delta makes it unlikely that a single large wildfire would impact the entire local riparian brush rabbit population. However, this habitat fragmentation also reduces the likelihood that rabbits displaced by a local fire would survive for long in surrounding agricultural and urban landscapes. Additionally, the close proximity of most remaining patches of habitat in the South Delta to roads, railways, canals, and residential areas increases the probability of human-caused wildfire ignitions (Syphard et al. 2007; Balch et al. 2017).

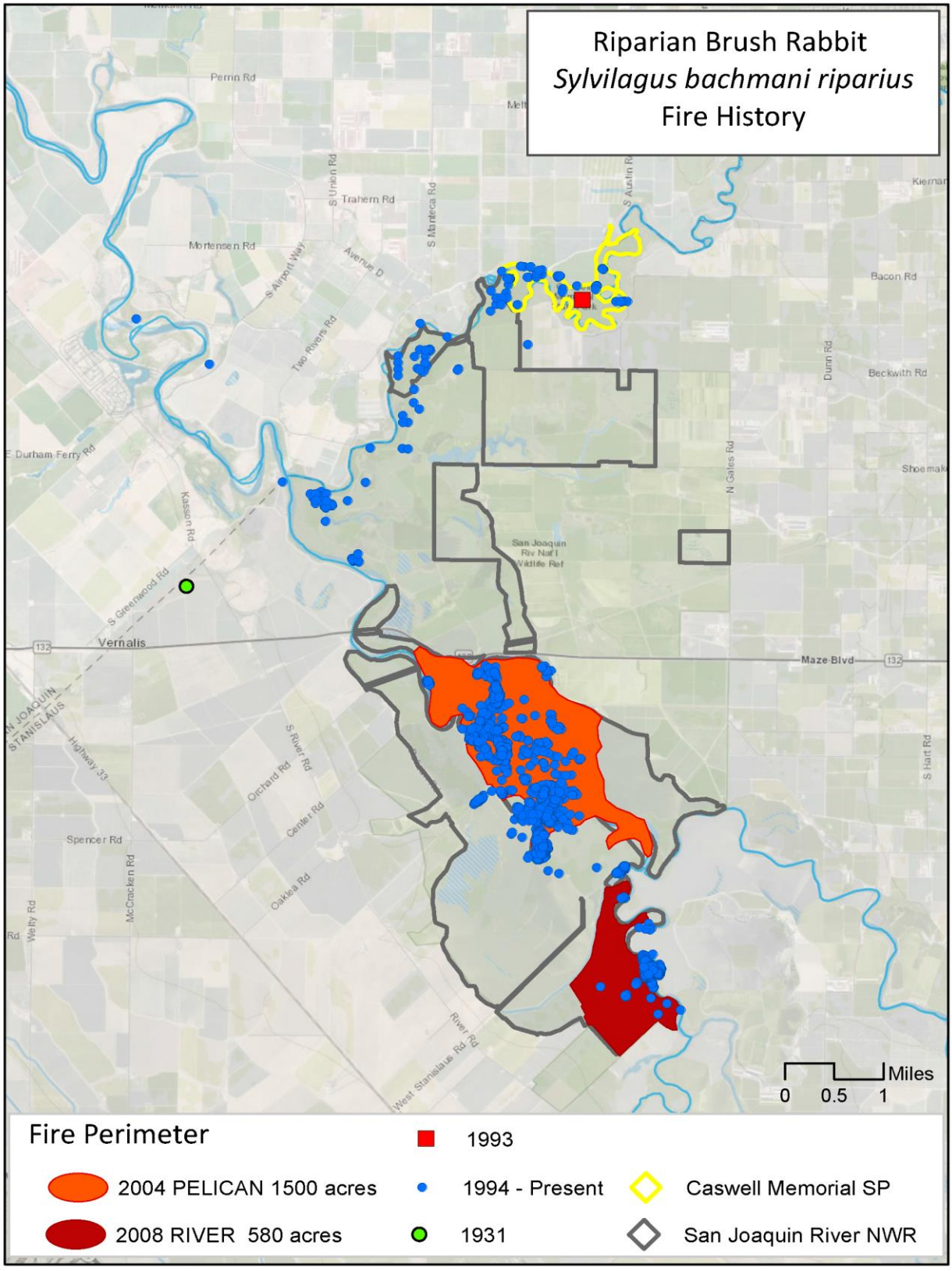

Figure 6. Areas burned in recent fires on the San Joaquin River National Wildlife Refuge.

ix. Invasive Species

The degree to which introduction of non-native and invasive plant and animal species in altered vegetation communities impacts the riparian brush rabbit populations is unknown. It is likely invasive species will continue to increase in abundance over time and impact native fauna to a greater degree (USFWS 2013). The degree to which invasive plant species can be utilized as cover and forage is unknown, although riparian brush rabbits are commonly found in Himalayan blackberry cover (*Rubus aremeniensis*). The impact of invasive mammalian predators is discussed under Predation above.

x. Rodenticides

Anticoagulant rodenticides such as brodifacoum, bromodiolone, chlorophacinone, diphacinone, and warfarin are highly toxic to mammals. Second-generation anticoagulant rodenticides such as brodifacoum and bromodiolone, which were introduced when rodents developed resistance to first-generation compounds in the 1970s, are particularly deadly (Gabriel et al. 2012, 2013; Thompson et al. 2014). First-generation compounds generally require several doses to cause intoxication, while second-generation anticoagulant rodenticides, which are more acutely toxic, often require only a single dose to cause intoxication or death and persist in tissues and in the environment (Gabriel et al. 2012). In the San Joaquin Valley and Delta, rodenticides are used to protect crops from California ground squirrels (*Otospermophilus beecheyi*) and other rodents and to prevent burrowing mammals from damaging levees and other water conveyance structures (Polo. Morelo pers. comm. 9/30/2019). Highly toxic rodenticide use is also commonly associated with illegal cannabis cultivation sites. Illegal cultivation sites have been found on the Refuge and at the riparian brush rabbit captive propagation breeding pens in San Joaquin County (USFWS 2006, Kelly 2018).

At one time, Caswell Park used broadcast rodenticides within the Park to control California ground squirrels (Basey 1990) and rodenticides were regularly used along the river levee north of the Park (Williams 1988). The Park no longer uses rodenticides to control ground squirrels. Similarly, the San Joaquin River National Wildlife Refuge utilizes integrated pest management to minimize pesticide use on Refuge lands so that exposure to rodenticides on Park and Refuge lands is not likely to pose a threat to riparian brush rabbits (USFWS 2000, USFWS 2006). However, riparian brush rabbits outside of these areas and individuals that disperse outside of the Park and Refuge remain threatened by rodenticide use (USFWS 2000).

The U.S. Environmental Protection Agency and the California EPA Department of Pesticide Regulation have cooperatively developed Pesticide Use Interim-Measures Bulletins to reduce the impact of pesticide use on listed species. These bulletins are supplemental pesticide labels which specify additional use limitations in and near listed species habitats in certain geographic areas (Polo Moreno pers. comm. 9/30/2019). One such limitation designed to provide protection for riparian brush rabbits specifies that a ≥ 15.2 m (50 ft.) cleared area must exist between the edge of dense riparian vegetation and the application of pelletized rodent bait. Alternatively, a T-shaped tube feeder must be used to dispense bait and be capped at night. Compliance with the bulletins is largely voluntary, although some county Agricultural Commissioners do incorporate

the protective measures into applicator permits making the provisions enforceable. Additionally, the US EPA has added endangered species considerations to certain rodenticides labels (e.g. chlorophacinone treated grain and diphacinone treated grain) which directs applicators to follow the relevant bulletins and allows Agricultural Commissioners to enforce the bulletin conditions. However, the labels of many common rodenticides do not yet reference endangered species considerations (e.g. zinc phosphide and wax block). Additionally, as the Pesticide Use Interim-Measures Bulletins for riparian brush rabbits only apply near dense riparian vegetation, they may not provide adequate protection for riparian brush rabbits occupying isolated blackberry-patches or riparian vegetation not deemed “dense” by applicators.

The number of riparian brush rabbits killed by rodenticides is unknown, but exposure to rodenticides may be a significant threat to riparian brush rabbits outside of Caswell Park and the Refuge. Rodenticides may prevent riparian brush rabbits from dispersing out of protected areas and limit the subspecies’ capacity to expand its range.

xi. Recreation

Information on the effects of recreational activities on riparian brush rabbits is mixed. Orr (1940) observed that brush rabbits ceased foraging for an average of 6 minutes following disturbance from humans which suggests repeated human disturbance may adversely affect riparian brush rabbits. Kelly (2018) noted that camping and day use activities in Caswell Park negatively impacted the local brush rabbit population. Conversely, Williams (1988) observed that riparian brush rabbits were common in campground areas and trailside thickets following a flood. However, it should be noted that Williams’ observations were made when park visitors were not likely to be present. The seasonal presence of recreating humans likely renders some portions of the Park temporarily unusable for rabbits. Outside of the Park, impacts to rabbits from recreation are likely negligible.

xii. Climate Change

Climate change is expected to impact riparian brush rabbits significantly through changes in flood frequency and magnitude due to changing precipitation patterns (see Flooding section above) and more frequent wildfires (see Wildfire section above). Climate change will likely impact riparian brush rabbit populations through other pathways as well, including drought, sea level rise, and acute heat stress.

Droughts in California have become increasingly extreme in recent years and are projected to become more frequent (Bedsworth et al. 2018; He et al. 2018). Although little is known about the impact of droughts on riparian brush rabbits, droughts could result in significantly reduced growth of the plant species riparian brush rabbits forage on, and prolonged droughts could result in substantial mortality in the shrub and tree species rabbits rely on for cover and food. Thorne et al. (2016) modeled a 15-24% reduction in the area that is currently climatically suitable for Central Valley riparian forest tree species by the end of the century under two future climate models using two future emissions scenarios, in part due to decreases in precipitation. Limited riparian brush rabbit population data from Caswell Park indicate a seven-year drought in the late 1980s and early 1990s did not negatively impact the local riparian brush rabbit

population (Williams 1993; Williams et al. 2000). This suggests the subspecies has some capacity to weather droughts within the normal range of historical variation, but the subspecies' ability to survive the projected unprecedented droughts of the future is unknown.

Mean sea levels in the San Francisco Bay are projected to rise 0.30-0.45 m (0.98-1.48 ft.) by year 2050, and 0.90-1.40 m (2.95-4.59 ft) by year 2100 from year 2000 levels (Cayan et al. 2012). As mean sea levels rise, the probability of flooding in the South Delta and lower San Joaquin River system increases when high tides and wet winter storms combine. By 2050, Delta levees may fail to meet the federal levee height standard of 0.46 m (1.5 ft.) freeboard above 100-year flood levels, and widespread flooding could occur in the South Delta and lower San Joaquin River (Bedsworth et al. 2018).

The mean annual maximum temperature in the San Joaquin Valley is projected to increase by 2.0-3.0°C (3.6-5.4°F) over the 1951-2013 mean by year 2050, and by 2.3-4.6°C (4.1-8.3°F) by the end of the century (He et al. 2018). No information exists regarding the riparian brush rabbit's ability to tolerate high temperatures, but the closely related desert cottontail becomes hyperthermic at temperatures above 30°C (86°F) and body temperatures begin to rise in relation to ambient temperatures. When body temperatures approach 45°C (113°F) desert cottontails die (Hinds 1973). Temperatures in the San Joaquin Valley have historically exceeded a heat index (a measure of how heat feels to organisms based on temperature and humidity) of 40.6° C (105° F) three days per year on average (calculated from Fresno, CA data). Projections indicate a heat index of 40.6° C will be exceeded an average of 59 days per year by the end of the century if no further action is taken to slow anthropogenic warming. Furthermore, conditions hotter than historically precedented (roughly equivalent to a heat index >58.3°C [137°F]) will be reached as many as 10 days per year in the northern San Joaquin Valley (Dahl et al. 2019). Such conditions would likely result in substantial brush rabbit mortality and possibly threaten the subspecies.

VI. MANAGEMENT AND RECOVERY

A. Impact of Existing Management Efforts

i. Captive Propagation

The Recovery Plan for the riparian brush rabbit set a goal of maintaining or establishing three self-sustaining, wild populations outside of Caswell Park within the historical range of the species (USFWS 1998). In 2001, a captive propagation and reintroduction program was initiated. This program was largely run by the Endangered Species Recovery Program of California State University Stanislaus in partnership with the USFWS, U.S. Bureau of Reclamation, California Department of Fish and Wildlife, California Department of Water Resources, California Department of Parks and Recreation, U.C. Davis Wildlife Health Center and Veterinary Medical Teaching Hospital, Sacramento Zoo, Center for Natural Lands Management, and River Partners with cooperation from private landowners in the South Delta who provided access for trapping breeding stock (Williams et al. 2002; Kelly 2018).

The program captured riparian brush rabbits in the South Delta, held them temporarily in outdoor breeding pens, and released their offspring into newly restored riparian habitat on the Refuge once they reached weights ≥400g and were screened by veterinarians (Kelly 2018). Releases began in 2002 and continued through 2013. During the initial five years of releases rabbits were fitted with radio collars, and information on dispersal, habitat use, and survivorship was collected. Rabbits were released into newly acquired Refuge lands and easements along the San Joaquin and Stanislaus Rivers which are contiguous with Caswell Park – connecting the Refuge population to the existing Park population. Over the course of the propagation program 1,496 riparian brush rabbits were released on Refuge lands (Kelly 2018). The riparian brush rabbit subspecies population has likely been dramatically augmented by this effort, although no quantitative monitoring has occurred to estimate the size of re-established populations since the captive propagation project was suspended in 2013 (Eric Hopson pers. comm. 8/27/2019, Patrick Kelly pers. comm. 8/28/2019). The increase in riparian brush rabbit distribution and abundance resulting from the captive propagation effort has increased the probability of more individuals surviving future flood events and other threats to breed and begin rebuilding populations. However, as noted above, essentially all of the current riparian brush rabbit range remains at risk of catastrophic flooding.

ii. San Joaquin River National Wildlife Refuge

The San Joaquin River National Wildlife Refuge was established 1987 to protect Aleutian Canada geese wintering on pastures and wetlands in north-central Stanislaus County (USFWS 2014). At the time, riparian brush rabbits were only known from the nearby Caswell Park. Beginning in 2002, captive-bred riparian brush rabbits were released on the Refuge as part of a comprehensive captive propagation program. The program continued through 2013 with a total of 1,496 riparian brush rabbits released. Today the Refuge has grown to approximately 4,047 ha. (10,000 ac.) of fee title and conservation easement land and it contains the largest extant local riparian brush rabbit population. Management for the recovery of the subspecies is now one of the Refuge's main objectives (USFWS 2014; Eric Hopson pers. comm. 8/27/2019).

Much of the Refuge is former farmland and dairy land which was converted from native land as early as the 1920s (Griggs 2012). In areas with suitable soils and hydrology, 1,093 ha (2,700 ac.) of Refuge land have been restored to riparian vegetation through the planting of native Fremont cottonwood (*Populus fremontii*), arroyo willow (*Salix lasiolepus*), black willow (*Salix nigra*), blue elderberry, coyote bush, Oregon ash (*Fraxinus latifolia*), and valley oak trees and by planting forbs and shrubs to establish an understory of mugwort, gumplant, and wild rye (*Elymus* sp.) (Griggs 2012). Within a few years of establishment, restored areas could support riparian brush rabbits. Along with riparian restoration, 34 flood refuge bunny mounds elevated approximately ten feet above the surrounding land were constructed on the Refuge. These refugia were planted with native tree and shrub species to provide food and cover to rabbits stranded by flood events (Griggs 2012, Kelly 2018).

The Refuge encompasses 324 ha. (800 ac.) of native riparian brush rabbit habitat and an additional 1,093 ha (2,700 ac.) of restored riparian forest at various stages of maturity. River Partners currently owns an additional 850 ha. (2,100 ac.) of riparian land at various states of restoration near the Tuolumne River – San Joaquin River confluence with the intent of annexing the land to the Refuge (Eric Hopson pers. comm. 8/27/2019). The USFWS was recently authorized to expand the Refuge by an additional 4,346 ha. (10,738 ac.) including approximately 3,440 ha (8,500 ac.) of additional riparian habitat (USFWS 2014). The authorized expansion includes lands extending approximately 34 km (21 m.) south from the existing Refuge boundary to provide connection to the Department's China Island Unit of the North Grasslands Wildlife Area (USFWS 2016). The North Grasslands is part of the Grasslands Ecological Area, a 64,750 ha (160,000 ac.) mosaic of protected San Joaquin River floodplain between Interstate 5 and State Highway 99 in Merced County. The area is a network of freshwater marshes (permanent and seasonal), alkali grassland, and riparian thickets conserved through conservation agreements with private duck clubs and land acquisitions by California State Parks (Great Valley Grasslands, Hatfield State Recreation Area), the Department (Volta, Los Banos, and North Grasslands Wildlife Areas), and the USFWS (San Luis and Merced National Wildlife Refuges and Grasslands Wildlife Management Area). Although only limited areas of the Grasslands Ecological Area are covered with riparian shrubs or forest, future expansion of the Refuge to connect to the ecological area would provide potential opportunities for riparian brush rabbits to disperse and significantly expand the area occupied by the subspecies.

The creation of the Refuge, ongoing riparian habitat restoration on the Refuge, and the continued expansion of the Refuge, coupled with the Refuge's role in the captive propagation program has greatly improved the viability of the riparian brush rabbit subspecies, although rabbits on the Refuge remain at substantial risk from flooding, fires, and other threats (Wittmer et al. 2016, Kelly 2018).

iii. Regional Habitat Conservation Plans

Areas of the riparian brush rabbit occupied range are covered by habitat conservation plans. Habitat conservation plans are regional plans approved by the USFWS that allow for regional development and specify avoidance, minimization, and mitigation measures for sensitive species. Habitat conservation plans can be used by signatories to authorize take of federally listed species under § 10(a)(1)(B) of the Endangered Species Act. The San Joaquin County Multi-Species Habitat Conservation and Open Space Plan covers the entire range of the riparian brush rabbit north of the Stanislaus-San Joaquin County line. Riparian brush rabbits are covered in the Plan, but the Plan does not authorize any take of the subspecies nor does it authorize the conversion of occupied habitat (San Joaquin Council of Governments 2000). Over the 50-year life of the plan, no more than 1.2 ha (3 ac.) of potential riparian brush rabbit habitat may be converted to other uses. Therefore, the riparian brush rabbit is protected from direct development-related impacts; however, other conversions of agricultural land to industrial and residential uses authorized under the plan effectively precludes opportunities for the future restoration of currently unoccupied lands and may limit opportunities for expanding occupancy in the County.

The Pacific Gas and Electric Company's (PG&E) San Joaquin Valley Operation & Maintenance Habitat Conservation Plan covers PG&E's lands, and gas and electrical transmission and distribution facilities on 111,835 ha (276,350 ac.) of the San Joaquin Basin (PG&E 2007). This Plan authorizes temporary and permanent impacts to a total of 0.6 ha (1.5 ac.) of riparian brush rabbit habitat over the 30-year life of the Plan. All activities are precluded from areas within 30.5 m (100 ft.) of occupied habitat as determined by a qualified biologist. Therefore, activities authorized under the Plan are unlikely to result in significant impacts to the riparian brush rabbit subspecies.

iv. Caswell Memorial State Park

A Resources Management Plan for the Sensitive Species of Caswell Memorial State Park was prepared by the California Department of Parks and Recreation in 1989 (Blankenship 1989). Portions of the plan related to riparian brush rabbits were largely based on the recommendations in Ecology and Management of the Riparian Brush Rabbit in Caswell Memorial State Park (Williams 1988). Actions in the plan include biannual monitoring of the local riparian brush rabbit population, control of feral cats and dogs, improving fuel breaks and fire lanes, and constructing flood refugia mounds. Caswell Park has been unable to implement riparian brush rabbit management activities in recent years because management funds are extremely limited and the status of the Caswell Park local population is currently unknown (Patrick Kelly pers. comm. 8/28/2019; Heather Reith, pers. comm. 8/29/2019).

B. Recommendations for Management Activities and Other Recommendations for Recovery of the Species

The Department's recovery objective remains unchanged from the 1993 Status Review: the protection and expansion of the existing subspecies population and reintroduction of a sufficient number of additional viable riparian brush rabbit populations in restored and permanently protected sites to insure their long-term survival within their native habitat and range. In order to achieve recovery, the remaining populations and any reintroduced populations must be free from significant threats, protected, monitored, and proven to be self-sustaining to the satisfaction of the Department and the Commission. The below management activities and recommendation are believed to be the most urgently needed to further the recovery of the riparian brush rabbit at this time.

i. Establishment of Additional Flood-secure Populations

The largest extant local riparian brush rabbit population on the Refuge is highly exposed to catastrophic flooding events, which are projected to become more frequent and severe. Other occupied areas in Caswell Park, the lower San Joaquin River, and the South Delta are also at risk from flooding. Bunny mounds and vegetated levees do not provide enough cover or forage to sustain large numbers of rabbits through prolonged flood events. There is an urgent need to establish riparian brush rabbit populations in large patches of high elevation suitable upland habitat. To achieve this goal the Refuge should consider acquiring high elevation parcels with potential to support riparian shrub and tree communities through the Refuge expansion process. Additionally, state and federal agencies should explore conservation easements and

management agreements with owners of high elevation land adjacent to occupied habitat to incentivize the establishment of brush rabbit cover and forage on portions of their land to act as refugia during flood events. Refuge staff should opportunistically translocate riparian brush rabbits to currently unoccupied areas of restored habitat within the Refuge such as the Dos Rios Ranch near the Tuolumne Confluence when animals are salvaged during flood events. Finally, state and federal wildlife managers should explore translocation of rabbits to suitable habitat on other refuge units such as the San Luis National Wildlife Refuge, the West Hilmar State Wildlife Area and units of the North Grasslands State Wildlife Area. Until large patches of suitable habitat above flood elevation can be secured, the limited existing high elevation flood refugia (e.g. bunny mounds and levees) should be planted with a mix of species selected to provide high quality forage during the typical mid-winter to early summer inundation period.

ii. Secure South Delta Populations

South Delta local populations continue to be under threat from habitat loss and fragmentation related to residential and commercial development and flood control projects. Very little of this genetically distinct population area currently exists on protected conservation lands. State and federal agencies should endeavor to acquire fee title or conservation easements from willing sellers to protect existing suitable habitat and to restore habitat on multiple large parcels with an emphasis on conserving genetically representative local populations.

iii. Complete a Recovery Plan

Prior to the subspecies' listing under the federal ESA, riparian brush rabbits were covered in the Recovery Plan for the Upland Species of the San Joaquin Valley (USFWS 1998). However, the plan did not include recovery criteria, and the plan was written prior to the captive propagation and translocation effort. The Department is authorized, contingent upon available funding, to develop and implement nonregulatory recovery plans for the conservation and survival of threatened and endangered species (Fish and G. Code § 2079.1(a)). An up to date recovery plan is needed to set goals and objectives and guide management actions for the recovery of the subspecies. Targets for the minimum number of viable populations, geographic distribution, and genetic conservation should be included in the plan, along with criteria for de-listing. The Department should consider collaborating with the USFWS to develop a joint recovery plan which satisfies the requirements of both agencies.

iv. Basic Research on Biology and Ecology

Basic information on the status of the riparian brush rabbit subspecies population and on riparian brush rabbit biology is needed to inform a recovery plan and to guide management. Wittmer et al. (2016) identified the need for research on the interaction between habitats and food availability, rabbit movement patterns, context-dependent predation, and the vital rates of established rabbit populations to inform population viability models. Other identified information needs include detailed studies of riparian brush rabbit diets (e.g. DNA analysis of scat contents and/or feeding trials) to inform planting of high elevation flood refugia, habitat restoration efforts, and land acquisition priorities (Patrick Kelly pers comm. 8/28/2019, Kim Forrest pers. comm. 9/20/2019). In order to inform management efforts to minimize competition between riparian

brush rabbits and desert cottontails, studies of the mechanisms that separate the respective ecological niches the two species are needed. In addition, development of rigorous and efficient surveying and monitoring techniques is needed to monitor the distribution and status of the riparian brush rabbit population (Kim Forrest pers. comm. 9/20/2019).

v. Fuel Management on Caswell Memorial State Park

The riparian brush rabbit habitat provided by the dense, mature, riparian forests of Caswell Park is at high risk of severe wildfire due to the accumulation of fuels at multiple canopy levels. Managing the fuel load in the Park will require carefully balancing the need to reduce the risk of catastrophic habitat loss from wildfire with the risks of degrading currently suitable habitat and fragmenting habitat patches through fuel treatments. The California Department of Parks and Recreation possesses management plans to accomplish these goals, but the agency lacks the funding to implement fuel reduction projects (Heather Reith pers. comm. 8/29/2019). Secure funding for fuels management within the Park is needed.

vi. Update Closed Hunting Zone

California Code of Regulations Title 14 §308(d) which prohibits the take of brush rabbits and cottontail rabbits in portions of San Joaquin County was added to California Code in 2002 with the intent of protecting riparian brush rabbits from hunting take. Since that time, riparian brush rabbits have been detected in additional areas outside of the hunting closure zone. The Department should consider updating the closure zone description such that it encompasses all known occupied habitat and present a regulation change proposal to the California Fish and Game Commission for consideration.

VII. RECOMMENDATION TO THE COMMISSION

Pursuant to Fish and Game Code section 2077, the Department has prepared this Five-Year Status Review based upon the best scientific information available to the Department to determine if conditions that led to the original listing are still present. Based on this Five-Year Status Review, the Department submits the following recommendation to the Commission:

In completing this Five-Year Status Review for riparian brush rabbit, the Department finds there is sufficient scientific information to indicate that the conditions that led to the listing of the riparian brush rabbit as endangered are still present. The riparian brush rabbit subspecies population is threatened by catastrophic floods, wildfires, threats related to small populations, predation, diseases, rodenticides, and climate change impacts. The Department recommends no change to the status of riparian brush rabbit on the list of endangered species at this time.

VIII. SOURCES

A. Literature Cited

J.P. Abatzoglou, and A.P. Williams. 2016. Impact of anthropogenic climate change on wildfire across western US forests. PNAS 113:11770-11775.

Balch, J.K., B.A. Bradley, J.P. Abatzoglou, R.C. Nagy, E.J. Fusco, and A.L. Mahood. 2017. Human-started wildfires expand the fire niche across the United States. PNAS 114:2946-2951.

Basey, G.E. 1990. Distribution, ecology, and population status of the Riparian Brush Rabbit *(Sylvilagus bachmani riparius).* Thesis, California State University, Stanislaus, Turlock, CA, USA.

Bedsworth, L., D. Cayan, G. Franco, L. Fisher, and S. Ziaja. 2018. Statewide Summary Report. California's Fourth Climate Change Assessment. California Natural Resources Agency Publication number: SUMCCCA4-2018-013.

Blankenship, D.S. 1989. Caswell Memorial State Park sensitive species management. California Department of Parks and Recreation. Unpublished project status report.

Bryant, H. C. 1918. Evidence on the food of hawks and owls in California. Condor 20:126-127.

California Department of Fish and Game (CDFG). 1993. Report to the Fish and Game Commission: Status Review of the Riparian Brush Rabbit (*Sylvilagus bachmani riparius*) in California. California Department of Fish and Game, Sacramento, CA, USA.

California Department of Water Resources. 2017. Central Valley Flood Protection Plan 2017 Update. California Department of Water Resources, Sacramento, CA, USA.

Cayan, D., M. Tyree, D. Pierce, T. Das. 2012. Climate change and sea level rise scenarios for California Vulnerability and Adaptation Assessment. California Energy Commission Publication number: CEC-500-2012-008.

Chapman, J.A. 1974. *Sylvilagus bachmani.* Mammalian Species No. 34. American Society of Mammalogists.

Chapman, J. A., J.G. Hockman, and W.R. Edwards. 1982. Cottontails: *Sylvilagus floridanus* and allies. Pages 83-123 *in* J.A. Chapman, G.A. Feldhamer, editors. Wild mammals of North America. Johns Hopkins Univeristy Press, Baltimore, MD, USA.

Chapman, J.A., and J.A. Litvaitis. 2003. Eastern cottontail. Pages 101-125 *in* G.A. Feldhammer, B.C. Thompson, and J.A. Chapman, editors. Wild Mammals of North America: Biology, management, and conservation. Johns Hopkins University Press, Baltimore, MD, USA.

Constable, J., S. Philips, D. Williams, J. Youngblood, and P. Kelly. 2011. Final Report: Characterization of genetic structure and phylogenetic relationships of riparian brush rabbit

populations. Prepared by the Endangered Species Recovery Program, Department of Biological Sciences, California State University Stanislaus, Turlock, CA, USA.

Das, T., E.P. Maurer, D.W. Pierce, M.D. Dettinger, and D.R. Cayan. 2013. Increases in flood magnitudes in California under warming climates. Journal of Hydrology 501:101-110.

Dixon, K.R., J.A. Chapman, O. Rongstad, and K.M. Orhelein. 1981. A comparison of home range size of *Sylvilagus floridanus* and *S. bachmani*. Pages 541-548 *in* K. Myers and C.D. MacInnes, editors. Proceedings of the world lagomorph conference. University of Guelph Press, Guelph, Ontario, Canada.

Elsholz, C.R. 2010. Riparian brush rabbit habitat requirements in Caswell Memorial State Park. Thesis, San Jose State University, San Jose, CA, USA.

Foster, G. L. 1927. A note on dietary habits of the barn owl. Condor 29:246.

Frankham, R. 2005. Genetics and extinction. Biological Conservation 126:131–140.

Gabriel, M.W., L.W. Woods, R. Poppenga, R.A. Sweitzer, C. Thompson, S.M. Matthews, J.M. Higley, S.M. Keller, K. Purcell, R.H. Barrett, G.M. Wengert, B.N. Sacks, and D.L. Clifford. 2012. Anticoagulant rodenticides on our public and community lands: Spatial distribution of exposure and poisoning of a rare forest carnivore. PloS ONE 7(7):e40163:1-15.

Gabriel, M.W., G.M. Wengert, J.M. Higley, S. Krogan, W. Sargent, and D.L. Clifford. 2013. Silent forests? Rodenticides on illegal marijuana crops harm wildlife. The Wildlife Society News. http://news.wildlife.org/twp/2013-spring/silent-forests/

Gavin, P.J., K.R. Kazacos, and S.T. Shulman. 2005. Baylisascariasis. Clinical Microbiology Reviews 18:703-718.

Gilardi, K.V.K., K.A. Terio, L.P. Hamilton, E.V. Williams, and D.F. Williams. 2004. Disease monitoring in captively-propagated and reintroduced riparian brush rabbits (*Sylvilagus bachmani riparius*) in California. Pages 297-298 *in* C.K. Baer, editor. Heath and conservation of captive and free-ranging wildlife; joint conference of the American Association of Zoo Veterinarians, the American Association of Wildlife Veterinarians, and the Wildlife Disease Association; San Diego, California, USA.

Griggs, T. 2012. Establishing roots: River Partners' long-term efforts on the San Joaquin River NWR. River Partners Journal. 8:5-7. https://www.riverpartners.org/wp-content/uploads/2018/08/Journal_2012-v8n1-winter.pdf

Hall, E. R. 1927. The bam owl in its relation to the rodent population at Berkeley, California. Condor 29:274-275.

Hall, E.R. 1981. The Mammals of North America, 2nd ed., Vol. 1. John Wiley and Sons, New York, NY, USA.

He, M., A. Schwarz, E. Lynn, and M. Anderson. 2018. Projected changes in precipitation, temperature, and drought across California's hydrologic regions. California's Fourth Climate Change Assessment. California Natural Resources Agency Publication number: CCCA4-EXT-2018-002.

Hedrick, P.W., and S.T. Kalinowski. 2000. Inbreeding depression in conservation biology. Annual Review of Ecological Systems 31:139-162.

Hinds, D. 1973. Acclimatization of thermoregulation in the desert cottontail, *Sylvilagus audubonii*. Journal of Mammalogy 54(3):708-728.

Ingles, L.G. 1965. Mammals of the Pacific States. Stanford University Press, Stanford, California, USA.

Katibah, E.F. 1984. A brief history of riparian forests in the Central Valley of California. Pages 23-29 *in* R.E. Warner and K.M. Hendrix, editors. California riparian systems ecology, conservation, and productive management. University of California Press, Berkeley, CA, USA.

Kelly, P.A. 2018. Reintroduction of the riparian brush rabbit in the San Joaquin Valley, California, USA. Pages 210-215 *in* P.S. Soorae, editor. Global reintroduction perspectives: 2018. Case studies from around the globe. IUCN/SSC Reintroduction Specialist Group, Gland, Switzerland and Environment Agency, Abu Dhabi, UAE.

Kelly, P.A., T.K. Edgarian, M.R. Lloyd, S.E. Phillips. 2011. Conservation principles for the riparian brush rabbit and riparian woodrat. Unpublished report prepared for the U.S. Fish and Wildlife Service Bay-Delta Fish and Wildlife Office, the California Department of Fish and Game, and the California Department of Water Resources. Prepared by California State University Stanislaus, Endangered Species Recovery Program, Turlock, CA. USA.

Kelly, P.A., and J.L. Holt. 2011. Quarterly report: controlled propagation and release of riparian brush rabbits in the northern San Joaquin Valley, California (1 January to 30 March 2011). Unpublished report prepared for the U.S. Fish and Wildlife Service San Luis National Wildlife Refuge Complex, the U.S. Bureau of Reclamation South Central Area Office, and the California Department of Fish and Game Nongame Wildlife Branch. Prepared by California State University Stanislaus, Endangered Species Recovery Program, Turlock, CA, USA

Kelly, P.A., and M.R. Lloyd. 2009. Draft annual report: controlled propagation and release of riparian brush rabbits in the northern San Joaquin Valley, California (1 July 2008 to 30 June 2009). Unpublished report prepared for the U.S. Fish and Wildlife Service San Luis National Wildlife Refuge Complex, the U.S. Bureau of Reclamation South Central Area Office, and the California Department of Fish and Game Nongame Wildlife Branch. Prepared by California State University Stanislaus, Endangered Species Recovery Program, Turlock, CA, USA.

Kelly, P.A., and M.R. Lloyd. 2010. Quarterly report: controlled propagation and release of riparian brush rabbits in the northern San Joaquin Valley, California (1 April to 30 June 2010). Unpublished report prepared for the U.S. Fish and Wildlife Service San Luis National Wildlife

Refuge Complex, the U.S. Bureau of Reclamation South Central Area Office, and the California Department of Fish and Game Nongame Wildlife Branch. Prepared by California State University Stanislaus, Endangered Species Recovery Program, Turlock, CA, USA.

Kelt, D.A., P.A. Kelly, S.E. Phillips, and D.F. Williams. 2014. Home range size and habitat selection of reintroduced *Sylvilagus bachmani riparius.* Journal of Mammology 95(3):516-524.

Krebs, C., S. Boutin, R. Boonstra, A. Sinclair, J. Smith, M. Dale, K. Martin, and R. Turkington. 1995. Impact of food and predation on the snowshoe hare cycle. Science 269:1112-1115.

Lloyd, M.R., K. Forrest, P.A. Kelly, J.L. Holt, T.K. Edgarian, and J.R. Rentner. 2011. Utilizing adaptive management in the recovery of the endangered riparian brush rabbit at the San Joaquin River National Wildlife Refuge, California. Poster session presented at Fish and Wildlife Service Conference Conserving the Future; Wildlife Refuges and the Next Generation, Madison, WI, USA.

Lloyd, M.R., and D.F. Williams. 2003. Riparian brush rabbit survey; Mossdale Landing, San Joaquin County, California, February 2003. Unpublished report prepared for Geoff Monk. Prepared by Endangered Species Recovery Program, Department of Biological Sciences, California State University Stanislaus, Turlock, CA, USA.

Matocq, M., P. Kelly, J. Rippert, and S. Phillips. 2017. Population genetic structure of the riparian brush rabbit (*Sylvilagus bachmani riparius*): using multiple marker systems to gain insight into historic and ongoing genetic connectivity. Report submitted to the CVPIA Habitat Restoration Program for Grant Agreement F13AP00564. U.S. Bureau of Reclamation Mid-Pacific Office. Sacramento, CA, USA.

Mossman, A.S. 1955. Reproduction of the brush rabbit in California. Journal of Wildlife Management 19:177-184.

Orr, R.I. 1935. Descriptions of three new races of brush rabbit from California. Proceedings of the Biological Society of Washington 48:27-30.

Orr, R.I. 1940. The rabbits of California. Occasional Papers of the California Academy of Sciences No. 19. California Academy of Sciences, San Francisco, CA, USA.

Pacific Gas and Electric Company. 2007. PG&E San Joaquin Valley Operation & Maintenance Habitat Conservation Plan. San Francisco, CA, USA.
https://ecos.fws.gov/docs/plan_documents/thcp/thcp_838.pdf

Phillips, S.E., L.P. Hamilton, and P.A. Kelly. 2005. Assessment of habitat conditions for the riparian brush rabbit on the San Joaquin River National Wildlife Refuge, California. Unpublished report prepared for the U.S. Fish and Wildlife Service Endangered Species Program, Sacramento, CA. Prepared by the Endangered Species Recovery Program, California State University Stanislaus, Turlock, CA, USA.

Phillip Williams and Associates. 2001. San Joaquin River National Wildlife Refuge Phase 1: Analysis of proposed levee breaches. Unpublished report prepared for Ducks Unlimited Western Regional Office and the U.S. Fish and Wildlife Service Anadromous Fish Restoration Program, PWA Reference number 1486. Prepared by Philip Williams Associates, Ltd., Corte Madera, CA, USA.

Primack, R.B. 1993. Essentials of Conservation Biology. Sinauer Associates Inc., Sunderland, MA, USA.

Primack, R.B. 2010. Essentials of Conservation Biology. Sinauer Associates Inc., Sunderland, MA, USA.

Reed, D.H., and R. Frankham. 2003. Correlation between fitness and genetic diversity. Conservation Biology 17:230-237.

Regnery, D.C., and J.H. Miller. 1971. A myxoma virus epizootic in a brush rabbit population. Journal of Wildlife Diseases 8:327-331.

Rippert, J.S. 2017. Population genetics and functional connectivity of the riparian brush rabbit (*Sylvilagus bachmani riparius*): Implications for the conservation of an endangered lagomorph. Thesis, University of Nevada, Reno, NV, USA.

River Partners. 2006. Restoration Plan for the Vierra flood protection and environmental enhancement project, San Joaquin River National Wildlife Refuge, San Joaquin River Mile 78L-88L, Stanislaus County, CA. Unpublished report prepared for Department of Water Resources and the U.S. Fish and Wildlife Service San Luis National Wildlife Refuge Complex. River Partners, Modesto, CA, USA.

River Partners. 2009. Riparian enhancement plan for the Arambel Unit, San Joaquin River National Wildlife Refuge, San Joaquin River Mile 78L-88L, Stanislaus County, CA. Unpublished report prepared for U.S. Fish and Wildlife Service and the U.S. Bureau of Reclamation Central Valley Project. River Partners, Modesto, CA, USA.

San Joaquin Council of Governments. 2000. San Joaquin County Multi-Species Habitat Conservation and Open Space Plan. Stockton, CA, USA. http://ca-sjcog2.civicplus.com/DocumentCenter/View/5

Singleton, L.A., S.L. Small, and T. Griggs. 2007. Effects of long-duration flooding on a San Joaquin Valley riparian restoration site. Page 30 in Riparian Habitat Conservation and Flood Management in California: Conference Proceedings. Riparian Habitat Joint Venture, CA, USA.

Sodhi, N.S., B.W. Brook, and C.J.A. Bradshaw. 2009. Causes and consequences of species extinctions. Pages 514-520 in S.A. Smith, editor. The Princeton Guide to Ecology. Princeton University Press, Princeton, NJ, USA.

Sumner. E.L. Jr. 1929. Comparative studies in the growth of young raptors. Condor 31:85-111.

Syphard, A.D., V.C. Radeloff, J.E. Keeley, T.J. Hawbaker, M.K. Clayton, S.I. Stewart, and R.B. Hammer. 2007. Human influence on California fire regimes. Ecological Applications 17(5):1388-1402.

Thompson, C., R. Sweitzer, M. Gabriel, K. Purcell, R. Barrett, and R. Poppenga. 2014. Impacts of rodenticide and insecticide toxicants from marijuana cultivation sites on fisher survival rates in the Sierra National Forest, California. Conservation Letters 7(2):91-1 02.

Thorne, J.H., R.M. Boynton, A.J. Holguin, J.A.E. Stewart, and J. Bjorkman. 2016. A climate change vulnerability assessment of California's terrestrial vegetation. California Department of Fish and Wildlife, Sacramento, CA, USA.

U.S. Fish and Wildlife Service (USFWS). 1998. Recovery Plan for the upland species of the San Joaquin Valley, California. Portland, OR, USA.

U.S. Fish and Wildlife Service (USFWS). 2000. Final rule to list the riparian brush rabbit and the riparian, or San Joaquin valley woodrat as endangered. 65 Fed. Reg. 36:8881-8890.

U.S. Fish and Wildlife Service (USFWS). 2006. San Joaquin River National Wildlife Refuge Final Comprehensive Conservation Plan. U.S. Fish and Wildlife Service California/Nevada Operations Office, Sacramento, CA, USA.

U.S. Fish and Wildlife Service. 2014. Proposed expansion San Joaquin River National Wildlife Refuge Environmental Assessment, Land Protection Plan, and Conceptual Management Plan. Sacramento, CA, USA.

Warner, M.D., C.F. Mass, and E. P. Salathé, Jr. 2014. Changes in winter atmospheric rivers along the North American west coast in CMIP5 climate models. Journal of Hyrdrometeorology 16:118-128.

Williams, D.F. 1986. Mammalian species of special concern in California. California Department of Fish and Game, Wildlife Management Division Administrative Report No. 86-1. Sacramento, CA, USA.

Williams, D.F. 1988. Ecology and management of the riparian brush rabbit in Caswell Memorial State Recreation Area. California Department of Parks and Recreation, Inland Region, Final Report, Interagency Agreement 4-305-6108. Sacramento, CA, USA.

Williams, D.F. 1993. Population censuses of riparian brush rabbits and riparian woodrats at Caswell Memorial State Park during January 1993. California Department of Parks and Recreation, Inland Region, and U.S. Fish and Wildlife Service San Joaquin Valley Endangered Special Recovery Planning Program. Turlock, CA, USA.

Williams, D.F., and G.E. Basey 1986. Population status of the riparian brush rabbit (*Sylvilagus bachmani riparius*), Contract Final Report. California Department of Fish and Game, Wildlife Management Division, Nongame Bird and Mammal Section. Sacramento, CA, USA.

Williams, D.F., P.A. Kelly, and L.P. Hamilton. 2002. Controlled propagation and reintroduction plan for the riparian brush rabbit (*Sylvilagus bachmani riparius*). Unpublished report prepared by the Endangered Species Recovery Program, California State University Stanislaus, Turlock, CA, USA.

Williams D.F., P.A. Kelly, L.P. Hamilton, M.R. Lloyd, E.A. Williams, and J.J. Youngblom. 2008 Recovering the endangered riparian brush rabbit (*Sylvilagus bachmani riparius*): reproduction and growth in confinement and survival after translocation. Pages 349-361 *in* P.C. Alves, N. Ferrand, and K. Hackländer, editors. Lagomorph Biology. Springer, Berlin, Heidelberg, Germany.

Williams, D.F., M.R. Lloyd, L.P. Hamilton, E. Vincent-Williams, J.J. Youngblom, K. Gilardi, and P.A. Kelly. 2005. Controlled propagation and translocation of riparian brush rabbits: annual report for 2003. Unpublished report prepared for the U.S. Bureau of Reclamation Mid-Pacific Region, the Fish and Wildlife Service Endangered Species Division, and the California Department of Fish and Game Species Conservation and Recovery Program. Prepared by the Endangered Species Recovery Program, California State University Stanislaus, Turlock, CA, USA.

Wittmer, H.U., D.A. Kelt, P.A. Kelly, and D.F. Williams. 2016. Use of simulation modeling to evaluate management strategies for reintroduced riparian brush rabbits in California. Journal of Fish and Wildlife Management 7(2):334–346.

Woolf, A., D.R. Shoemaker, and M. Cooper. 1993. Evidence of Tularemia regulating a semi-isolated cottontail rabbit population. Journal of Wildlife Management. 57(1):144-157.

B. Personal Communication

Warden Adam Cahn, California Department of Fish and Wildlife, Central Enforcement District, Fresno, CA. 6/17/2019.

Captain Ryan Detrick, California Department of Fish and Wildlife, Central Enforcement District, Fresno, CA. 6/17/2019.

Kim Forrest, Refuge Supervisor, U.S. Fish and Wildlife Service, San Luis National Wildlife Refuge Complex, Los Banos, CA. 9/20/2019.

Katherine Heffernan, Wildlife Biologist, U.S. Fish and Wildlife Service, San Luis National Wildlife Refuge Complex, Los Banos, CA. 6/4/2019 email to Stephanie Prevost, U.S. Fish and Wildlife Service, describing observations of rabbits stranded by flood waters on San Joaquin River National Wildlife Refuge.

Eric Hopson, Wildlife Biologist, U.S. Fish and Wildlife Service, San Luis National Wildlife Refuge Complex, Los Banos, CA. 8/27/2019.

Dr. Patrick Kelly, Endangered Species Recovery Program, Stanislaus State University, Turlock, CA. 8/28/2019.

Warden Jeffrey Moran, California Department of Fish and Wildlife, Central Enforcement District, Fresno, CA. 6/17/2019.

Polo Moreno, Senior Environmental Scientist, California Department of Pesticide Regulation, Sacramento, CA. 9/30/2019.

Stephanie Prevost, Wildlife Biologist, U.S. Fish and Wildlife Service, Listing and Recovery Division, Sacramento Fish and Wildlife Office, Sacramento, CA. 6/13/2019.

Stephanie Prevost, Wildlife Biologist, U.S. Fish and Wildlife Service, Listing and Recovery Division, Sacramento Fish and Wildlife Office, Sacramento, CA. email dated 10/22/2019.

Heather Reith, Senior Environmental Scientist, California Department of Parks and Recreation, Central Valley District, Columbia, CA. 8/29/2019

Lieutenant Eric Vielhauer, California Department of Fish and Wildlife, Central Enforcement District, Fresno, CA. 6/17/19.

C. Other

City of Lathrop. 2019. City of Lathrop, CA Planning Division Specific Plans Information website accessed at https://www.ci.lathrop.ca.us/planning/page/specific-plans.

Federal Emergency Management Agency. 2019. National Flood Hazard Layer. Geospatial Data accessed at https://hazards.fema.gov/gis/nfhl/rest/services/public/NFHL/MapServer.

IX. LIST OF FIGURES